Physics Department Self-Study Report for the Academic Program Review

Elliott Cheu, Kenneth Johns, Sumit Mazumdar, Ina Sarcevic, Charles Stafford, Bira van Kolck, Charles Wolgemuth

April 6, 2018

Abstract

This report contains material for the Academic Program Review of the physics department at the University of Arizona. The report covers the years from 2011-2017.

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Abbreviations Used in this Report

AA Academic Advisor. 50, 59

ABOR Arizona Board of Regents. 25, 27

ABR American Board of Radiology. 75

AFOSR Air Force Office of Science Research. 32, 34, 35, 38, 39

AIP American Institute of Physics. 54, 57

AMO Atomic, Molecular, and Optical physics. 15, 16, 19–21, 25, 28, 33, 35, 45, 64, 75

AMS Accelerator Mass Spectrometer. 37

APR Academic Program Review. 1, 5, 10, 11, 17, 45, 48, 72

APS American Physical Society. 32, 67, 76

ARO Army Research Office. 35, 38–40

ASO Academic Support Office. 48–50

ASU Arizona State University. 35

BPP Biological Physics Program. 35, 74

CAMPEP Commission on Accreditation of Medical Physics Education Programs. 24, 62

CAS Chinese Academy of Sciences. 32, 34

CBC Chemistry and Biochemistry. 19

CERN European Center for Nuclear Research. 15, 37

CIP Classification of Instructional Programs. 53, 62

CM Condensed Matter physics. 15, 16, 45

COOS College of Optical Sciences. 10, 14, 19, 74, 75

COS College of Science. 5, 6, 10, 15, 17, 19, 22, 24, 26, 27, 32, 34, 43, 48–51, 56, 57, 72, 73, 77

CUWiP Conferences for Women in Physics. 20

D2L Desire2Learn. 56, 64

DARPA Defense Advanced Research Projects Agency. 35, 40

DDM Dynamical Dark Matter. 37

DES Dark Energy Survey. 36

DESC Dark Energy Science Collaboration. 32

DGS Director of Graduate Studies. 23, 24, 48, 50, 67, 70, 71

DOE US Department of Energy. 26, 32, 34, 36–40, 42, 43, 64

DUGS Director of Undergraduate Studes. 22, 23, 48, 50, 56, 60, 61

DUNE Deep Underground Neutrino Experiment. 32

ECE Electrical and Computer Engineering. 14

EFT effective field theory. 36

EHT Event Horizon Telescope. 32

FIAP Forum on Industrial and Applied Physics. 76

FLC Faculty Learning Communities. 56, 76

GIDP graduate interdisciplinary program. 74

GPC Graduate Program Coordinator. 50, 52

GPSC Graduate and Professional Student Council. 67

GSC Graduate Student Council. 20

ICR Indirect Cost Recovery. 15, 26, 77

JTUPP APS Joint Task Force on Undergraduate Physics Programs. 12, 13, 76

LCDM Lambda Cold Dark Matter. 36

LHC Large Hadron Collider. 15, 32, 37

LIGO Laser Interferometer Gravitational-Wave Observatory. 32

LISA Laser Interferometer Space Antenna. 32

LSST Large Synoptic Survey Telescope. 16, 20, 21, 32, 36

MCB molecular and cellular biology. 74, 75

MRSEC Materials Research Science and Engineering Center. 15, 42

NASA National Aeronautics and Space Administration. 32, 38, 39

NIH National Institutes of Health. 38, 39, 42, 75

NRC National Research Council. 25, 42

NSF National Science Foundation. 26, 32, 34, 35, 37–40, 42, 63, 71, 72

OIA Office of Instruction and Assessment. 22, 43

OIE Office of Institutional Equity. 20

OSA Optical Society of America. 38, 40

PSM Professional Science Masters. 6, 10, 23, 24, 62, 63, 75

QCD Quantum Chromodynamics. 36

RCM Responsibility Centered Management. 10, 12, 17, 24, 26

REU Research Experience for Undergraduates. 13, 20, 42, 72, 73

SACNAS Society for the Advancement of Chicanos/Hispanics and Native Americans in Science. 13

SCH student credit hours. 17, 26

SFAz Science Foundation of Arizona. 32, 34, 35, 38, 39

SFP French Physical Society. 34

SRI Summer Research Institute. 66

STC Science and Technology Center. 15

TAP Theoretical Astrophysics Program. 19, 21, 32, 45, 74

TCE Teacher-Course Evaluations. 43

TIMESTEP Tucson Initiative for Minority Engagement in Science and Technology Program. 57

TUSD Tucson Unified School District. 72

UA University of Arizona. 1, 5, 6, 10, 12–18, 21, 22, 25–29, 32, 34, 35, 37, 43, 46, 54–57, 59, 64–66, 68, 69, 71, 73, 76, 77

URM under-represented minorities. 13, 66, 76

UTEP University of Texas at El Paso. 66

WIMP Weakly Interacting Massive Particle. 36

WiP Women in Physics. 20, 24, 57, 73

WISE Women in Science and Engineering. 20

A Self Study Summary

The physics department at the UA is one of fifteen departments within the College of Science (COS) and it reports to the Dean of the COS. There are 28 tenure/tenure track faculty in the department including six assistant professors, four associate professors and eighteen full professors. The list of faculty members is given in Table 8. The department also has two senior lecturers, whose primary roles are teaching, and no adjunct instructors. A third lecturer will join the department in August 2018. A total of nine postdoctoral research associates and four research scientists help the department maintain a robust research program.

The physics department offers B.A. and B.S. degrees in physics and a minor in physics. The two bachelors degrees enroll 241 students (fall 2016), with the vast majority of students enrolled in the B.S. degree. In fall 2016 the department had eight students enrolled in the B.A. degree. Twenty six students are enrolled in the physics minor. The graduate program offers a Ph.D. in physics and a Professional Science Masters (PSM) degree in medical physics. There is no separate physics M.S. program, however the degree is awarded to students enroute to a Ph.D. or as a terminal degree. There are currently (fall 2016) 89 students enrolled in the Ph.D. program and four students in the PSM medical physics program.

The Self Study report that follows was constructed by the department's Academic Program Review Committee, consisting of eight faculty members, including the head and the associate head. The report is divided in several sections that present detailed discussions of the following topics.

• Unit Description and Goals, section B. This section presents the strategic plan for the department, which is aligned with the UA's *Never Settle* strategic plan, as well as the UA's Responsibility Centered Management (RCM) approach to budgeting.

• Unit History, section C. This section lists the changes that have occurred within the department since the previous APR that took place in 2011, the recommendations from the previous APR and the changes made in response.

• Academic Quality, section D. This section presents external and internal rankings of the department, and comparisons with five peer institutions.

• Faculty, section E. This section presents a comprehensive discussion about the faculty's research interests, achievements and funding. It also includes the roles played by physics faculty in the greater physics community, the extent and quality of teaching, recent hires, faculty compensation, and diversity among the faculty.

• Unit Administration and Resources, sections F and G. These sections discuss departmental governance and resources.

• Undergraduate Program, section H. This section gives a comprehensive review of the undergraduate education program with detailed discussions of curriculum, enrollment, student credit hours, graduation times, ethnic composition and diversity of the student body, and learning outcomes assessment.

• Graduate Program, section I. This section gives the same information as section H, except for the graduate program.

• Academic Outreach, section J. This section discusses the departmental outreach efforts directed towards the local community, with the goals of public education, recruitment of undergraduate students and solicitation of donations to the department.

• Collaboration with Other Units, section K. This section presents discussions of departmental collaborations with other campus units. Collaborations at individual faculty level and departmental level exist with the departments of astronomy, planetary sciences, chemistry and biochemistry, biological sciences, mathematics, the College of Optical Sciences (COOS), and the medical school.

• Faculty Planning, section L. This section presents the faculty's collective view of the program's future. Much in this section overlaps strongly with what has been presented in section B. The emphasis here is on (i) how the goals of section B will be implemented and, (ii) the challenges the department faces in the short and long terms.

The overarching goal of this Self Study report is to give a comprehensive picture of the achievements and progress of the department since the last APR in 2011, the department goals for future, the challenges faced in preparing students for the workplace of the future, faculty hiring, and the resources that will be needed to meet these challenges.

B Unit Description and Goals

B.1 Department Mission and Alignment with the UA Strategic Plan

The mission of the physics department is excellence and achievement in teaching, research, and service. The department's strategic plan seeks to continue to improve and innovate in these areas.

The new president of UA, Dr. Robert Robbins, is in the process of developing the strategic plan for his administration. Here we refer to the strategic plan developed by the past president, Dr. Anne Weaver Hart.

The mission of the physics department is aligned with the UA's *Never Settle* strategic plan. The website for this plan (formerly at www.neversettle.arizona.edu) has been removed, but is partially archived at `http://wayback.archive-it.org/8954/20171114180448/http://neversettle.arizona.edu/`. The mission of this plan is "to improve the prospects and enrich the lives of the people of Arizona and the world through education, research and creative expression, and community and business partnerships". The pillars of the *Never Settle* strategic plan are engagement, innovation and partnerships.

The goals of the physics department align with these pillars. Engagement includes recruitment and retention of a diverse student body and providing students with a dynamic educational experience. The department strives to deliver to students a high quality classroom experience coupled with student participation in the research programs of faculty in the department or in other related departments across campus. Innovation includes promoting core strengths to address grand challenges and expanding opportunities for interdisciplinary collaboration. Many of the faculty research programs are attacking some of the most important questions in their fields in order to make significant advances forward. There is significant collaboration between the department and other units across campus as described in Section K. One of the desired outcomes of the partnership pillar is to increase the number of people with expertise in critical fields such as STEM. The department strives to support this outcome by preparing undergraduate and graduate students to solve next generation problems.

Any realistic strategic plan in the department must also be aligned with the UA Responsibility Centered Management (RCM) (`http://rcm.arizona.edu`) approach to budgeting. The objectives include encouragement and reward for revenue generation and cost effectiveness. At the departmental level, the strategic plan is constructed with the goals of strengthening students academically and encouraging faculty innovation. At the same time the department strives for an enhanced ability to plan with a better sense of future resource flows. It should be recognized at the outset that a realistic strategic plan, even as it sets out well-defined goals, must be flexible enough that it does not become outdated before implementation is completed. It is with all of these in mind that the following plan was constructed.

B.2 Department Strategic Plan

B.2.1 Undergraduate and Graduate Student Engagement

The different elements of this plan have evolved and been modified with faculty input. In general, with direction from the head, department committees study and generate a plan to achieve some goal or outcome. The plan is presented at one or more faculty meetings, where it is possibly modified or returned for further work. In the case of the Applied Physics major, a faculty vote was taken for approval.

- Creation of a new undergraduate major in Applied Physics

  The motivation for creating an applied physics major comes both from the extensive work done by the APS Joint Task Force on Undergraduate Physics Programs (JTUPP) (`http://compadre.org/jtupp`) as well as our own experience. JTUPP points out that 7500 US students graduate with a bachelor's degree in physics annually, of which only 350 will be hired as faculty members in Ph.D.-granting institutions and four-year colleges. Nearly 40% of physics graduates enter the workforce immediately, of whom 60% work in the private sector. While there are approximately 220 physics majors at UA each year, the number of completed majors each year is approximately 20. Clearly a significant fraction of majors, many of whom love physics, have not been retained.

It makes sense then to ask ourselves whether we are preparing the majority of our students for the diverse careers that they may have after obtaining their physics degree. Even without the excellent work by JTUPP, data on student career plans have compelled us to create this major. Approximately 50% of our graduates do not enroll in graduate programs in physics or astronomy. These students often report frustrations finding private-sector jobs or otherwise planning their post-baccalaureate career. The Applied Physics program, currently a proposal to be submitted to the UA, is designed to train these students in real-world problem-solving and give them a competitive advantage in career paths outside traditional physics. Specifically, the applied physics major is designed to serve undergraduates intending to (a) enter the workforce in the engineering, information technology, or financial sector, or (b) obtain advanced degrees in a related field such as engineering, chemistry or medicine, or (c) obtain educational or advising positions in science and public policy.

The students targeted for this degree are ones who enjoy physics but do not have long-range plans for academic careers in physics or are reluctant to pursue a major that does not lead in a clear way to a career outside of academia. Our experience with Research Experience for Undergraduates (REU) programs and minority-student conferences such as Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) has shown that this attitude is particularly prevalent among under-represented minorities (URM). An anticipated side benefit of the applied physics major will be improved recruitment and retention of URM's in the department.

The curriculum for the proposed applied physics major was inspired by the JTUPP report, which emphasized four learning goals for any such program: (i) physics-specific knowledge, (ii) scientific and technical skills, (iii) communication skills, and (iv) professional and workplace skills. While there is a substantial overlap in required coursework between the physics and applied physics majors, the latter will replace 18 units of upper-division physics coursework with the following:

- A required course in statistics/computing/data mining
- A required course in scientific communication
- A year-long engineering design project (ENGR 498A and 498B) in which students will work on a problem from industry with a student team from other science and engineering fields.
- A set of four technical electives (including physics) focused on the student's career interests

The technical electives will be chosen with close advising from faculty. The curricula for the applied physics and (comprehensive) physics degrees will be identical for the first two years. Students will differentiate after mandatory advising at the end of their sophomore year.

A number of institutions similar to UA have successful and well-established applied physics programs, e.g., Rutgers University, Purdue, Georgia Tech, Iowa State, and UC Davis. In some of these cases applied physics is further subdivided into career-specific curricular strands (e.g. UC Davis), and in other cases the elective focus is handled at the advising level (e.g. Iowa State and Rutgers). The department has taken the latter approach as a starting point. Future evolution of the program will be based on student outcomes. In most institutions, the applied physics majors number roughly 1.5 times the number of physics majors, and a similar result is expected here, based on student surveys.

New majors require administrative approval at several levels, starting with Curricular Affairs and ending with the Board of Regents. We anticipate submitting the full proposal in 2018 and offering the new major beginning in fall 2019. Upon approval, faculty will advertise the new major to our existing undergraduates, at UA majors fairs, directly in classrooms at local high schools, and at Pima Community College, a major source of transfer students to UA. A number of our faculty have connections at these feeder institutions via our REU program, and through informal student internships.

- Distance learning and UA Online

With the increasing demand for workers and employees in STEM fields there has been a concomitant increase in the demand for distance learning. Many professional programs require their students to take introductory physics courses. The physics department recognizes both the challenges and the opportunities here and has begun to collaborate with the UA Online program (http://uaonline.arizona.edu) to create fully online introductory algebra-based and calculus-based introductory physics courses. An obvious goal is that all UA online courses have the same high quality as the classroom ones.

The plan is to develop these courses as faculty are available to work on them. Our goal is to develop courses in collaboration with UA Online that are of outstanding quality, similar to those developed by other campus units. Colleagues at UA Online have been enthusiastic and supportive, and have been eager to make the initial investments (in the form of an instructor salary and TA stipend).

The first online course developed was for PHYS 102, which is the department's algebra-based introductory physics course. The goal here is to provide support to the College of Architecture's online Bachelor of Science program in Sustainable Built Environments (http://capla.arizona.edu/degree/sustainable-built-environments). The program currently has 30 students and UA Online expects to double the enrollment by Fall 2019.

During the summer of 2017, senior Lecturer Shawn Jackson worked with UA Online to develop the course, which was offered for the first time during the second half of the fall semester of 2017. The course had an enrollment of just three students, one of whom successfully completed the course. One possible reason for the low enrollment was the absence of an accompanying online laboratory course, corresponding to PHYS 181. In collaboration with UA Online, the online lab course is presently being developed, with TA Kyle Leaf as the instructor. PHYS 102 with an option to include PHYS 181 will be offered for the first time in Fall 2018. A physics faculty member will oversee the initial offering of this combination of courses. The department plans to train and mentor physics graduate students, who in turn will oversee and serve as instructors of record for its subsequent online course offerings.

The physics department has just hired a third lecturer who will free up faculty time to create additional, high quality online courses. The department plans to build three other need-based online courses, again proceeding one step at a time. These are PHYS 141 (introductory calculus-based mechanics), PHYS 143 (introductory thermodynamics and optics), and PHYS 241 (introductory electricity and magnetism). The goal is to provide support for the College of Engineering online Bachelor of Science program in Electrical and Computer Engineering (ECE) (http://uaonline.arizona.edu/programs/undergraduate/online-bachelor-science-electrical-and-computer-engineering-bs). (As an aside, Arizona State University, which has been ahead of UA in creating online courses, has 1200 online ECE students).

There is also demand for these physics courses from students enrolled in the Bachelor of Applied Science in Meteorology (http://uaonline.arizona.edu/programs/undergraduate/online-bachelor-applied-science-meteorology-applied-science-bas) that was created by the department of Hydrology and Atmospheric sciences. The latter component in particular has already been very successful (with an enrollment greater than thirty) as it serves the educational needs of military personnel desiring to be promoted to professional meteorologists. Current online ECE and meteorology students take their physics courses externally. We believe that there is a great opportunity here for the physics department. Especially helpful is that the initial (for the first three years) financial investments will be provided by UA Online. Discussions on this are ongoing between the department administration and UA Online.

- Future Careers for Graduate Students

  While many of our graduate students secure excellent postdoc positions after their Ph.D., the fraction of students eventually obtaining a faculty position is small. An important goal for the graduate program is to better educate the graduate students about future career possibilities. A subset of faculty are discussing how best to educate and perhaps provide supplemental training for the graduate students seeking non-academic careers. While the problem is complex, the department has a goal of creating a well-defined path and support for graduate students to better prepare them for a variety of future careers. Ideas include the creation of a 1 unit course for grads on "Careers after Your Ph.D.", the invitation to Ph.D. alumni working in industry to speak to the graduate students in a semi-formal setting, an annual job fair, and the use of LinkedIn and other similar services to provide a community of Ph.D. alumni from the department. In addition, the department will give credit in the major for skill related elective courses such as is offered as part of graduate certificate in science communication http://cos.arizona.edu/content/graduate-certificate-science-communication.

B.2.2 Faculty Hiring and Innovation

Physics is distributed across the UA campus, with faculty and researchers in multiple campus units (such as in the departments of astronomy and planetary sciences and the COOS) engaged in physics research. This has been both advantageous and disadvantageous to the physics department. On the positive side, many physics faculty collaborate on a regular basis with faculty from the other campus units, and have held joint grants and have joint appointments in these units. Similarly, several faculty from other units hold joint appointments in physics and a small number are involved in teaching physics courses on a long term basis. On the negative side, the existence of these other units as distinct entities has limited the faculty size within the physics department itself. The department currently has twenty eight tenured and tenure-track faculty members. In spite of seven new hires over the past five years, this number remains approximately constant due to retirements.

To increase our grant income, influence on various fields, and national ranking, it is agreed upon within the department that the faculty size should rise to 32 - 36 over the next five years. This is a challenging goal given current College of Science (COS) resources. With anticipated retirements, such an increase would require at least two, and perhaps more, successful faculty searches per year. A hire rate of one per year will actually lead to an overall decrease in the number of faculty in the department.

The composition of the department in terms of theorists and experimentalists needs to be improved. This is dictated by the need to have a healthy Indirect Cost Recovery (ICR) as well as broad research options for graduate students. In general, the start-up cost for table-top experimentalists is significant (˜$1M per faculty). Nevertheless, we believe that multiple hires in experimental areas, especially in Condensed Matter physics (CM) and Atomic, Molecular, and Optical physics (AMO), are not only essential but also strongly justified by the success of all our recent hires in securing large external research grants as well as garnering national recognitions and awards.

The hiring plan below consists of two parts: the first describes the minimal hiring the department must have to maintain the faculty size and to slowly improve our ICR and national ranking. This is referred to as Hiring Plan 1. A second plan, Hiring Plan 2, is a bolder plan involving cluster hires above and beyond Hiring Plan 1. This plan would improve the ranking of the department sharply over a short period. Both plans recommend building on the existing strengths within the department (or at the very least, within the UA) rather than pursuing new directions.

- Hiring Plan 1

  This plan, constructed by a hiring plan advisory committee of elected faculty, envisions the hiring of eight experimentalists over the next five years. The goal is to achieve an experimentalist to theorist ratio of three to two. The present ratio is approximately one to one. The critical areas are thought to be experimental CM and AMO, biophysics, experimental particle physics and cosmology.

  The CM/AMO group currently consists of both senior and junior faculty with various common research interests, and interaction between these faculty members and the students from the different research groups is leading to visible benefits in the form of joint publications and grants. However, the total number of experimental CM/AMO faculty (five including a 2017 hire) remains below the critical mass required for securing federal funding for the creation of large UA-based research centers, such as Materials Research Science and Engineering Centers (MRSECs) and Science and Technology Centers (STCs). The advisory committee determined that three to four hires in CM/AMO physics are urgently needed, and the department as a whole has endorsed this. Given the complementarity of biophysics to CM/AMO physics, and the strength of the life sciences programs across the campus, we also propose a hire in experimental biophysics, preferably of a researcher whose interests overlap with Wolgemuth in physics or with UA faculty outside physics. Overlap in research interests here with faculty in the medical school would be a plus.

  Along with the above hires we will pursue hires in experimental particle physics and cosmology. The experimental particle physics group has provided significant ICR returns to the department over the past several decades. It has recently decreased in size due to a retirement and a second retirement within a couple years is likely. In spite of its success in the ATLAS program at the European Center for Nuclear Research (CERN) Large Hadron Collider (LHC) and in the department, there has been no new hire in this research area since 2002. Given the international visibility of the group, the accomplishments of the individual researchers, and the level of interest among graduate students to pursue research in this area of physics, at least two hires within the next five years are warranted. Otherwise the group is in danger of falling below a critical mass needed to garner above average funding.

Within the physics department proper there is currently a single faculty member, Rozo, with research interest in cosmology. Given the significant Large Synoptic Survey Telescope (LSST)-based activities within the UA campus, as well as the very recent hires in this area in the department of astronomy, the benefits of the anticipated synergy strongly justifies a hire in this area.

Finally, it is re-emphasized that any hiring plan be flexible. Even as the primary target in faculty hiring is to increase the proportion of experimentalists, we recognize that the average age of theorists in the department, especially in particle-nuclear theory and condensed matter theory groups, is getting to be unacceptably high. The department plans to eventually hire in both areas. As in the past, should there be an opportunity to make an excellent hire at the intersection of particle and nuclear physics, it will be seriously considered. The recent hire of Meinel is an example of such an opportunity hire.

- Hiring Plan 2

  This plan envisions cluster hires over and above Hiring Plan 1, built around two pillars. One of these would leverage existing programs in the high energy cluster in the department: particle theory and experiment, cosmology, astrophysics theory and experiment, gravitational waves and nuclear theory. The second would build around the existing CM/AMO effort. The goal in both cases is the same: to give a large boost to the existing research programs that can then successfully vie for large projects/funding beyond single-PI grants. Job opportunities for Ph.D. students were also considerations in the selection/identification of these pillars.

  Pillar 1 is centered around data science. A cluster hire of three faculty members, one each in the areas of experimental particle physics, cosmology and gravitational waves is envisioned. All three new faculty members would be hired for their experience and expertise in data science and/or machine learning. These faculty members would contribute to existing programs in the department including the LSST/cosmology effort. A strong nucleus of expertise in data science could contribute to data science projects in other fields. This is especially important as it relates to health science, a field that is just beginning to realize the range of possibilities data science brings. There are several large scale projects already on campus that can be used to leverage new ones in data analytics. Overall, building research efforts around this pillar will not only give a boost to research within the department, but will also build bridges across campus units.

  Pillar 2 is centered around experimental CM/AMO physics. The CM/AMO program has significant strength in 2D quantum materials (LeRoy, Schaibley, Wang), spintronics (Wang, Zhang), and ultrafast optical science (Hassan, Sandhu). Cluster hires of two-three faculty that complement the existing experimental efforts in the department are envisioned. Research areas of particular interest are crystal growth and device fabrication, quantum electronics including topological transport and quantum information, and novel spectroscopy techniques. There is additional interest in seeing growth in these research areas in other campus units. Cluster hires cutting across departments are desirable.

C Unit History

C.1 Major Changes That Have Occurred Since the Last APR (2011)

Many changes, large and small, have occurred since the previous APR. In several cases, the changes were undertaken in response to recommendations from that APR. The following are the most important changes, as perceived by department members.

- *Responsibility Centered Management (RCM)*

  The adoption by the UA of RCM, whose goal is "to provide an incentives-based transparent budget model for the University of Arizona," has meant that the department has had to focus more intensively than before on revenue generation and cost effectiveness. While this has brought certain benefits (greater individual accountability, for instance), it has also been accompanied by uncertainties. For example, the funding for "temp teaching", primarily graduate student TA (Teaching Assistant) stipends, that the department receives from the College of Science (COS) is no longer a constant number that can be relied upon each year. The temp teaching funding now depends on the difference between the extents of teaching (measured in student credit hours (SCH)) between the two previous academic years. Aside from the year to year short term uncertainty, the decreasing college age population in the US has long term implications for any budget model that is so strongly dependent on continuous growth. The physics department, along with other campus units, is currently watching to see how this problem is resolved at the University level.

- *Hiring of new faculty members*

  Seven new faculty members have been hired. As described elsewhere (Section E), all the new hires have been remarkably successful in their teaching and research missions. All have garnered numerous national and international awards. The hiring predominantly in experimental physics has better balanced the number of experimentalists and theorists in the department, however the ratio has not reached our desired goal of three to two.

- *Hiring of a professional advisor*

  Physics advisor Holly Brown was hired in 2016. She is able to expertly guide students through the various administrative procedures and also plays a significant role in alerting students to research opportunities. She sends students periodic checklists to help keep them on track. She promotes opportunities for women in science as they arise. Faculty continue to have a role in student advising but focus more on discussing different career paths in physics with the students.

- *Reduction in department staff*

  Necessitated by the state-imposed budget cuts, the department administrative, business and academic support offices now operate with a smaller (by about 30%) number of staff. One staff member (systems manager Mike Eklund) is shared between the departments of physics and hydrology and atmospheric science. While technological innovations have allowed the requisite services to students and faculty to continue, the smaller staff still presents occasional challenges.

- *Greater emphasis on teaching quality*

  There is far greater emphasis on the quality of classroom instruction, TA training and assessment. To an extent, this has been necessitated by RCM, but much credit goes to the Director of Undergraduate Studies and the Teaching Evaluation Committee. Modest funding through an AAU grant to UA to improve undergraduate STEM education allowed the department to transform the introductory physics course for engineers (PHYS 141) from a lecture-based course to one that emphasizes active learning. We subsequently transformed the second semester of this sequence (PHYS 241) as well as the two algebra-based physics courses (PHYS 102 and PHYS 103). As a result of this transformation, a significantly larger number of faculty members use active learning techniques in their courses, including upper division ones.

- *Greater emphasis on outreach*

  A Physics Discovery Program has been initiated, whose mission is to expose visiting school groups to physics education and research. Physics Open Day, which coincides with the Tucson Festival of Books that is hosted at UA, began in 2012. Several experimental laboratories are open for multiple 30 minute tours, members of the Physics Club perform demonstrations around a central theme at Science City, and the day concludes with a public lecture in the department by a UA faculty member or alumnus. Science City is a large area with several diverse science themes. There are hands-on activities, physics demonstrations, and presentations/performances for each.

  The department hosted two High School Days in 2014 and 2015. Approximately 40 students in 2014 and 95 students in 2015 visited the department for an afternoon. They toured a variety of physics labs in the department and learned about the positives of becoming a physics major at UA. More information on outreach can be found in Section J.

- *Increased gifts*

  Gift donations to the department have increased significantly. Donor money has helped to provide modest scholarships and travel support to conferences for graduate and undergraduate students, renovation of the graduate student lounge, and purchases of student computers and new equipment for the Advanced Lab experiments. As of writing, there are ongoing discussions of setting up of an endowment that will double the yearly income coming from donations.

- *Distance learning and online courses*

  As discussed in Section B.2, an online algebra-based introductory physics course (PHYS 102) has been developed and was offered in Fall 2017. The accompanying online lab (PHYS 181) will be ready by Fall 2018. There are plans to develop the corresponding calculus-based introductory mechanics course (PHYS 141, including lab), introductory thermodynamics and optics (PHYS 143), and introductory electricity and magnetism (PHYS 241, including lab).

- *Focus on undergraduates preparing for the workforce*

  It is recognized that the present physics degree under-serves those students who choose to work in industry or government labs over continuing to graduate school. For that reason, we are in the process of establishing a B.S. degree in Applied Physics. This degree is intended for the above population of students. For this degree, the requirement of some upper division physics courses is replaced by courses in communication, computing and/or statistics, and a two-semester engineering design program taken by many engineering students. This course emphasizes team building across multiple disciplines, including now physics.

C.2 Recommendations from the Previous APR and Changes Made in Response.

The previous APR was held at a time of considerable turmoil for both the department and the University. The recommendations from the APR stressed the need to continue to have an independent physics department that maintains excellent relationships with other campus units and the University administration, as well as pursues excellence within the physics department itself. The following are individual APR recommendations and the actions taken by the department in response.

- APR recommendations concerning relationships with other campus units

  At the research level there are many healthy cross-unit relationships that involve faculty from the physics department. However there is a need to develop and improve unit to unit relationships at the level of the department and school heads. Such relationships are needed to allow discussions such as aligning of course sequences, avoidance of unnecessary course duplications, and providing support to non-physics students...

  Responses

At the time of the previous APR the Theoretical Astrophysics Program (TAP) (`https://tap.arizona.edu`) was functioning at a less than optimal level, primarily due to the departures of several senior faculty, including the then Chair of the program. In 2010 the then department heads of astronomy, planetary sciences and physics met with COS Dean Joaquin Ruiz to nominate faculty Renu Malhotra from planetary sciences for the position of Chair of the TAP program. The Dean made the new appointment and the TAP has since thrived. Malhotra stepped down as Chair in 2016, when faculty Dmitrios Psaltis from the astronomy department was appointed as the new chair of the program, again with unanimous agreement by the current department heads. The TAP Steering Committee consists of two faculty members from each of the three departments. Two new hires have been made since 2010 and all five faculty positions that had been created by the State of Arizona specifically for this program are now filled. Sam Gralla joined the physics department in 2015 and Vasileios Paschalidis joined the astronomy department in 2017. Paschalidis also holds a joint appointment in the physics department.

There is a similarly strong interaction between physics faculty with research interests in condensed matter and Atomic, Molecular, and Optical physics (AMO) physics and Chemistry and Biochemistry (CBC)faculty with research interests in physical chemistry. The Chemical Physics Program (`http://chemphys.arizona.edu`) has received strong support from both department heads. Mazumdar has a joint appointment in CBC. Three CBC faculty have received joint appointments in physics.

The physics department and the COOS agreed to conduct joint faculty searches in AMO physics in 2016. The collaboration was both at the unit head level and at the level of the search committees. The collaboration allowed the two units to bring in significantly larger-than-usual number of candidates to the campus for interview. The search resulted in the hiring of Mohammed Hassan in physics.

Co-convening of the first semester of the graduate quantum mechanics course with the COOS had begun in 2009, even prior to the previous APR. This occurred largely because of a top-down push from the then provost's office. The physics department agreed to this proposal, in spite of reservations within the department about the level at which the subject was taught in optical sciences and about the topics that were not covered in their course. The level of the textbook that was being used by optical sciences until then is generally considered to be suitable for an advanced undergraduate physics course.

These concerns were brought to the attention of COOS faculty. It was agreed between the COOS and the physics department that instructors from COOS would teach the course for the first three years followed by an instructor from the physics department. However, COOS instructors continued to use the syllabus they had used prior to the agreement. As a consequence physics department instructors had to make significant adjustments in teaching the second semester of quantum mechanics, which is a core course for physics graduate students. Further, when it was time for physics department faculty to teach the first semester course in 2012, COOS reneged on their agreement to co-convene the course. Following this somewhat unhappy experience, the physics department has not attempted further co-convening of courses. In general the rigor expected in courses taught by instructors from the physics department proper presents difficulties for students from other campus units, which in turn makes co-convening difficult.

- APR recommendations concerning "Climate" within the department

  While a new Department Head has made some progress in ameliorating past issues of a divided and, for a time, headless Department with a difficult internal climate, the problem is not solved. It will take strong action from the University as well as the Department Head to incentivize faculty to improve the situation. It appears that a few difficult individuals have been allowed to act and speak in ways that create a hostile environment for women and a general lack of collegiality in the Department. This needs to be reversed.

  Responses

  Strong proactive measures were taken to improve the climate within the department and, in general, it has functioned as a cohesive unit since the last APR. Major effort has gone into consensus building. Annual faculty retreats are held at the beginning of each academic year. A hiring plan for the entire department was constructed by a representative committee consisting of seven faculty members (25% of the faculty) whose members were picked by the entire faculty.

The department is strongly committed to creating and maintaining a work and learning environment that is safe, inclusive and free of discriminatory conduct. Faculty and staff have been made aware of the department's zero tolerance policy for any behavior that may be interpreted as harassment. Faculty and staff have undergone online training regarding the requirements of Title IX (preventing sexual misconduct) provided by the University's Office of Institutional Equity (OIE). Incoming graduate students and undergraduate freshman receive Title IX training at the beginning of their careers. Each year a representative from OIE is invited to talk at a faculty meeting to discuss changes or answer general questions.

Student climate is improved through the separate graduate and undergraduate student lounges that are provided by the department. Each year, separate graduate and undergraduate town hall meetings are held with the head and other department administration to hear any complaints or ideas for improvements in the department. For several years, a poll for graduate students was administered by the Graduate Student Council (GSC) in the physics department (at their own initiative) and a few questions were related to the climate in the department. In recent years, the GSC has chosen not to conduct a poll, but the topics the poll was designed to probe are often discussed during the annual town hall meeting. Once or twice a year, an informal BBQ for faculty and students is hosted by the Women in Physics (WiP) club or the Research Experience for Undergraduates (REU) program. Students are also invited the department's annual Christmas party.

The existence of a gender gap in physics is widely recognized by the physics community. The physics department believes in taking a proactive role in fighting this. Subsequent to the previous APR the department has had a very active WiP group that was created by the students themselves (`http://arizonawip.weebly.com`). The WiP is part of the larger community of Women in Science and Engineering (WISE) at the University of Arizona. The objectives of the WiP include "to help foster an inclusive and respectful atmosphere for everyone in the physics department at the University of Arizona". The group organizes regular discussion lunches, brings in occasional seminar speakers and has been involved in a variety of outreach activities that promote interest in STEM education among elementary and middle school students. The department encourages and also financially supports these activities of the WiP. The department also encourages undergraduate women and under-represented minority students to attend APS conferences and pays travel expenses for all participants to Conferences for Women in Physics (CUWiP) meetings.

- APR recommendations concerning faculty hiring

  (i)... appointment of an experimental particle astrophysicist is now being considered by the Department. Such an appointment would match well with the interests of the high energy experimental group's particle astrophysics effort..., and offer a strong intellectual community in this department. This last, the Large Synoptic Survey Telescope (LSST), is a telescope to be built in Chile, designed to make a deep and broad survey of the distributions of galaxies and dark matter throughout space, in order to probe questions about dark energy and structure formation in the Universe (among others). Thus this new activity also represents a transition from high energy particle physics to particle astrophysics, a wise and future-oriented decision, ...

  (ii) It is the view of this committee that some growth of the AMO effort in the Physics Department would be entirely appropriate.

  (iii) Considering the rapid growth of this field (Biophysics), its complementarity to condensed matter and optical science in the department and to the Chemistry-Biochemistry and Biology departments on campus, this is an opportune area for expansion in Physics.

  (iv) The group (condensed matter physics) and the department needs to formulate a plan for growth in this area for attracting both young and senior experimentalists who will lead this effort for the years to come. The University needs to support growth in this area. .... Unlike some other fields of physics it is not broadly represented in other units across the campus, but it is a core area of physics that any university must have.

  (v) With this pattern, is seems to us a question as to whether the department is well served to continue to hire in astrophysics. If the decision is made to do so, a plan to prevent yet another repeat of this history will be needed, ...

  (vi) Thus this two groups (theoretical high energy and nuclear physics) actually form a single continuum of interests with significant overlaps of interest... While all these three subgroups have an appetite for

growth, and the nuclear theorists spoke to their desire to have experimental colleagues, we did not see any pressing needs in this area.

Responses

We emphasize that there had existed general consensus within the department already about hiring in the above research areas. While our subsequent hires have largely followed along the lines suggested in the APR, we have also deviated substantially in some cases (specifically v and vi, see below), based on our own perception of the direction most appropriate for us.

(i) There is general agreement within the department that there should be hires in this area of research. A similar opinion has been emphasized by the Departmental Hiring Committee and additional discussions can be found in our current Strategic Plan. The physics department hired Eduardo Rozo in 2014. Rozo's expertise is in developing methods to identify and characterize large galaxy clusters. He is a Co-Chair of the Clusters Working Group within the Dark Energy Science Collaboration effort of the LSST.

(ii) John Schaibley, whose research interests overlap both condensed matter physics and AMO physics, was hired in 2016. Mohammed Hassan, whose research involves generation of ultrafast attosecond light pulses and attosecond electron microscopy was hired in 2017.

(iii) Dr. Charles Wolgemuth, whose research intersts lie in biological cell motility and and cell-cell interactions, was hired as an Associate Professor in 2012. Wolgemuth was promoted to Full Professor in 2016.

(iv) The department agrees that hiring at junior as well as senior levels in condensed matter physics would be desirable, but considering the resources that would be required to hire at a senior level, we have refrained from doing so until now. Two faculty members were hired as junior faculty. Weigang Wang, with research interest in nanomagnetism and spintronics, was hired in 2012. He is up for promotion to Associate Professor with tenure this (2017-2018) academic year. John Schaibley, who is interested in two-dimensional materials and device physics was hired in 2016.

(v) Contrary to recommendations from the last APR, the department hired Sam Gralla, whose research is in theoretical astrophysics in 2015. This decision was part of the shared overall plan between the departments of astronomy, planetary sciences and physics to reinvigorate the TAP. TAP faculty searches proceed in an unbiased manner and the successful candidate may choose the department he/she wants to join. Sam has made significant contributions to the department's teaching, research, and outreach missions since joining the faculty.

(vi) We agree completely with the APR that the high energy and nuclear physics theory groups form a single continuum of interests. In contradiction to the suggestion made by the APR reviewers, based on faculty departures, retirements and potential retirements, it was decided to make a hire in this area of physics. Stefan Meinel, whose research interests, not coincidentally, overlap both high energy and nuclear physics, was hired in 2014. Meinel is currently also a RHIC Physics Fellow at the RIKEN BNL Research Center, but will be a full time employee of the University in 2019. At this time he will also go up for tenure and promotion to Associate Professor. As with Gralla, we are proud of Meinel's achievements subsequent to his arrival at the UA.

- APR recommendations concerning undergraduate education

  (i) ...the absence of a faculty committee devoted to Undergraduate education and a plan to review and improve curriculum and instruction is a notable lack. The responsibility for deciding course teaching assignments has been delegated to a person with a continuing teaching appointment (not tenure line) who holds the title of Director of Undergraduate Education. This seems to us a significant abrogation of faculty responsibility.

  (ii) There has been considerable research in recent years on how to teach physics more effectively; we feel that this resource has not been adequately utilized by the department, although some individual faculty members have adopted a few of the suggested approaches. A cohesive attitude of openness to these new approaches to physics education would open up the department in may ways, such as producing a more supportive atmosphere with less of the "weed-out" mentality, which students felt still dominates introductory courses.

  (iii) In particular, a purely lecture format for first-year students and for non-physics majors has been shown to be largely ineffective. In such courses, most students, even those who succeed on problem-solving tests, gain very little on tests of understanding of physics concepts. Improving the quality

of teaching in service courses will help to enhance relationships with other Departments at UA.... Improving the quality of teaching throughout the two-year sequence for physics majors will improve the retention and recruitment of students in the department...

(iv) The lab courses need attention. A recurring comment was that first-year labs are not coordinated with class topics, and the lab manuals use a dated, "cook book" approach. It was also expressed by undergraduate students that TAs often seemed unfamiliar with the lab or could provide little assistance when a student had problems with equipment. In addition, lab TAs themselves commented that they felt like they did not receive enough training in grading and in lab processes.

(v) ...we question whether the most current laboratory instrumentation is being used for the first year labs. We were told that certain labs could not be revised because the existing computers had outdated laboratory interfaces that were incompatible with modern software. With updated lab equipment and software, it should be straightforward to come up with more inquiry-based labs that would be more meaningful to students and would illustrate physics principles more clearly.

Responses

(i) At the time of the APR we already had a curriculum committee that continuously reviewed the curriculum. Over and above this, we created the Teaching Evaluation and Improvement Committee in 2011. It was initially tasked with observing all our new TA's in one of their laboratory sections. The observations are unannounced, which pressures the TA's to be always prepared. After the observation, we meet with them and make suggestions for improvement. If deemed necessary, we observe TA's a second time. In the spring of 2017, the committee's duties were expanded to include peer observations of faculty based on a protocol developed by the University's Office of Instruction and Assessment (OIA). Each faculty member will be observed approximately once per year. For now, this is a formative review, providing faculty with constructive feedback. In the future it may become part of our annual faculty performance evaluation.

(i) Regarding the appointment of non-tenure track lecturer Drew Milsom as the Director of Undergraduate Studes (DUGS), this was not an abrogation of responsibility. Rather, considerable thinking led to this assignment. Milsom had taught all the undergraduate courses, several graduate courses, was personally familiar with all majors, knew his counterpart in the department of astronomy personally (all astronomy majors are also physics majors), was up to date with University policies and regulations and above all, was willing to invest the significant time and energy needed to be successful. As an aside, it is pointed out that several other departments within the COS have similar personnel performing the same job, for precisely the same reasons. The improvements in teaching techniques that have occurred in the department (see below) have come primarily through the efforts of Milsom.

In 2014, following the 5-year review of department head Mazumdar, he conducted a survey of the physics faculty on the performance of Milsom as DUGS. The physics faculty overwhelmingly supported Milsom's reappointment.

(ii) and (iii) Since the Fall of 2013, the physics department has introduced extensive evidence-based active learning components into our large introductory service courses, both algebra-based and calculus-based. The efforts were jumpstarted through an AAU grant to UA to improve undergraduate STEM education. Five UA departments including physics were part of the proposal. Milsom (DUGS) subsequently provided the leadership within physics.

The grant provided modest funds that allowed creating materials for active learning sessions that would replace some of the regular lectures. Some of the materials are similar to those used/created at other universities but many are original, created by Milsom and collaborators. Materials that emphasized active learning during lecture were also produced. The department strongly supported this effort.

Presently, each of the courses PHYS 141 (calculus-based introductory physics), PHYS 102 and 103 (algebra-based physics sequence) and PHYS 241 (calculus-based electromagnetism) has replaced one lecture per week with an active learning tutorial. In PHYS 141 students are divided into sections of 24 students and work in groups of four in a room. The sessions are facilitated by one graduate student and one undergraduate preceptor. Tutorial sessions for PHYS 102, 103 and 241 are held in one of the UA's collaborative learning spaces. Once again, the sessions are facilitated by multiple graduate students, undergraduate preceptors, and in these cases, also by the faculty members. Importantly, these curricular materials are also used by faculty in the honors versions of these courses taken by the physics majors.

Active learning course materials for an intermediate level mathematical methods course and for the year-long upper division electromagnetism course have also been developed by faculty LeRoy and Milsom respectively. Overall, approximately one half of our faculty members have used some of these active learning materials in their classes.

(iv) and (v) The introductory physics labs (PHYS 181 and lab portion of PHYS 141) were completely overhauled by LeRoy. New equipment was purchased for all the experiments (for example, wireless motion carts). Some of the new equipment allowed us to create completely new experiments. For example, we now have a roller coaster track that can be used for experiments related to energy conservation and circular motion. In another example, a two dimensional air table and a video camera permit the students to analyze collisions in 2D. The experiments use modern data acquisition with recently purchased Windows-based PC's. The PHYS 141 lab emphasizes creativity and is organized into two-week units. During the first week, the students learn how to use some equipment and to make various measurements. During the second week, the students must develop an experimental plan to measure something specific using the skills learned in the first week. The students must submit their research plan to the course management site 48 hours before their lab meeting so that the TA can evaluate their plan.

We plan to modify next the algebra-based electromagnetism/optics lab - PHYS 182. A shortage of teaching faculty has delayed the execution of this plan. The very recent hiring of a third lecturer in the department will free up resources that will allow regular faculty to devote time to this task.

As to TA training, new policies have been implemented. TAs are required to practice the lab they are going to teach, a week before. There is adequate preparation to ensure that the TA walks into the class well prepared, with excellent knowledge of the theory, procedure and how to use the appropriate instruments. In the beginning of the fall semester, before TA's are assigned their teaching responsibilities, all incoming graduate students are required to give a 15-minute presentation, where they show their teaching and communication skills in front of 25-30 observers including Lab Manager Rohit Singh, DUGS Milsom and Director of Graduate Studies (DGS) Fleming. They basically teach a lab that they chose to practice a week before class starts. Job assignments are made based on teaching and language skills. Additionally, all incoming graduate students go through 24 hrs (3 hours each Friday for 8 weeks) of TA training in which they are taught how to grade quizzes, lab reports and exams. They are also taught how to facilitate small groups of students working on tutorial problems. This training is conducted by DUGS Milsom. The TAs must pass this training in order to continue to teach.

- APR recommendations concerning graduate education

  (i) The Professional Science Masters (PSM) degree program in medical physics is currently underenrolled, but is expected that certification of the program will increase enrollment. This is a valuable component of the University's portfolio of opportunities for the students and needs to be nurtured to become self sustaining.

  (ii) Mentoring of graduate students, particularly in their first two years before they join a research group appears to be inadequate. Although the graduate students are largely content with their situations there was general concern on knowing what was required of them at different stages of their careers. In particular in the time before they have an official thesis advisor they feel somewhat adrift. They know that they can be in touch with the director of graduate studies and they know of the existence of two other faculty who are officially available for consultation, but few take advantage. We suggest the institution of a mentoring system that begins when students are accepted, and follows them until they complete their Ph.D. A system which has worked well in other notable physics departments is to assign a committee of two faculty members to each entering student. The committee meets with the student periodically (every 6 months) until the student graduates. Their role is to assure that each student knows what is expected, has at least two mentors, and after getting a thesis advisor, has three faculty members familiar with his research (e.g. for writing recommendations).

  (iii) Another of the student complaints was a stated feeling of bait and switch for those finding a Ph.D. supervisor with faculty in other departments. Before enrolling they were told of the ease of finding advisers outside physics. But it appears that there is a asymmetry in the research assistantship support offered to physics students working for outside advisors and outside students working for physics advisors, partly due to the physics department policy of financially supporting all their students. Both the students and faculty realize this as a problem which must be addressed, but in a way that does not lead to uncertainty for the students, possibly simply by a clearer explanation of what is expected.

(iv) However this situation raised another issue that the students face. If they have a problem with the department administration they have no place to turn except the administration itself. The chair and other department members stand ready to hear from the students and respond to their concerns, but this can put students in an uncomfortable position, one which feel confrontational to them. The system needs an Ombudsman either at the department or the college level. A mentoring committee that includes individuals other than the thesis advisor can also help ameliorate this situation.

Responses

(i) In 2012 the PSM program in medical physics program achieved Commission on Accreditation of Medical Physics Education Programs (CAMPEP) accreditation, and due to the ever increasing clinical workload, the Dean of the College of Medicine, Charles B. Cairns, M.D., allocated one FTE to support the teaching mission of the physics section. This brings the number of faculty members in this group to six. In the accreditation year, 2012, three students were enrolled. Subsequently in 2013 five students enrolled, in 2014 two students enrolled and in 2015 three students enrolled. In 2016, due to a variety of complications no students were admitted. However, five students were admitted in 2017 and the plan is to add five to seven more students in 2018. This program is very popular and we have no problem recruiting very strong students.

(ii) We have implemented a mentoring system for incoming students, though they are assigned to a senior graduate student rather than a faculty member. This is done in coordination with the physics Graduate Student Council, and appears to be working quite well. In addition, after the completion of the comprehensive exams students are required to give a yearly progress report to a committee chosen by the student with the advisor as the head. This is to prevent students from drifting off as they move away from the structured class format to a less structured research format. The committee ensures good progress by the student and good mentoring by the advisor. It also provides additional familiar faculty members from whom the student can receive advice.

(iii) The current policy is to treat all physics graduate students on equal footing regardless of which department their advisor resides in. For example, with the move to the RCM model, and as undergraduate enrollment fell in the COS, in the Fall 2017 semester we did not have enough funding to support all of the students requesting TA's. Priority for funding went to junior students first and to senior students last regardless of the department to which the advisor belonged.

(iv) While there is no Ombudsman at the department or college level, there is a University Ombudsman that students can contact. Currently within the department we have two student groups, the Physics Graduate Student Council and the WiP, to which the students can voice their concerns. The DGS has a good working relationship with both groups and not only responds to concerns, but also incorporates suggestions. For example, after the aforementioned TA crisis, the DGS met with the Graduate Student Council and discussed the situation. These meetings were open to all students, and were well attended. A number of suggestions were made by the students that were subsequently adopted. Most important of these was a request for more transparency, and earlier notice. As a result the DGS has kept the graduate students updated in real time with the situation regarding the TA's in Spring 2018. Hopefully this will relieve some anxiety, and allow students to plan further in advance. Unfortunately, our ability to keep students informed is limited by the information we receive from the college.

D Academic Quality

D.1 External Rankings

One measure of program quality can be found from various external rankings. For the undergraduate physics program, we know of no available external ranking other than for the UA as a whole. In the 2018 rankings from US News and World report, the UA is ranked 124th in National Universities out of 1806 schools.

Two national rankings of the physics department doctoral programs exist. One is from US News and World Report and the other is from the the NRC (National Research Council) publication, "A Data-Based Assessment of Research-Doctorate Programs in the United States". Published in 2011, the latter is now somewhat dated, having used data collected during the academic year 2005-2006.

The 2018 US News and World Report ranking of graduate physics programs ranks the UA program 37th out of 146, tied with Boston University, Indiana University at Bloomington, New York University, Purdue University, the University of California (UC) Santa Cruz, and the University of Florida. Universities ranked directly above UA (tied for 35th) are Carnegie Mellon University and Brown University. Schools ranked directly below UA (tied for 44th) Arizona State University, the University of Rochester, and the University of Virginia. The Atomic, Molecular, and Optical physics (AMO) program at the UA is ranked 10th, tied with the University of Rochester.

The U.S. News and World Report rankings are based solely on the ratings of academic experts. The rank of the UA Physics Department has been at this level (between 30th and 40th) for the last decade or more. As given by US News and World Report, the top six graduate programs in physics are Massachusetts Institute of Technology, Stanford, California Institute of Technology, Harvard, Princeton and UC Berkeley. While we should always look to the best for new program ideas and initiatives, these universities are different from the UA in significant ways and there is little to be gained by comparison with them. Another comparison is the rankings of the physics departments at our official Arizona Board of Regents (ABOR) peers: UC Davis, UCLA, University of Florida, University of Illinois, University of Iowa, University of Maryland, Michigan State University, University of Minnesota, University of North Carolina, Ohio State University, Pennsylvania State University, University of Texas, Texas A&M University, University of Washington, and the University of Wisconsin. We are ranked in the bottom third of this group according to U.S. News and World Report.

The National Research Council (NRC) last published their study of doctoral programs in the physical sciences in 2011, using data collected during 2005-2006, from 212 universities and provides a range of rankings rather than a single number. Actually two ranges are given in the publication. One is an S-ranking (for survey-based), which uses a faculty survey on the relative importance of various measures to develop ranges of rankings. The other is an R-ranking (for regression-based), which uses a smaller faculty survey on program rankings to obtain weights for program variables so as to closely reproduce those rankings. In the associated spreadsheets accompanying the NRC publication, one finds the S-ranking range (5th to 95th percentile) for the UA Physics Department to be 58-113 and the R-ranking range to be 51-99. Compared to our ABOR peers given above we are second from the bottom. The top two schools from our peers are the University of Illinois (S-ranking 3-14 and R-ranking 13-60) and the University of Texas (S-ranking 4-17 and R-ranking 25-80).

What can one conclude from these rankings? The UA physics department is not a top 20 program by most measures. This is not surprising given the department's size and resources. However, by most measures, the physics department will be found in the second tier of programs below the top ones. Certainly, there are numerous instances of research and teaching excellence in the department as well as outstanding faculty who are at or near the top of their fields. One of the department's long-term goals is to continue to improve its educational and research excellence as outlined in the strategic plan. Slightly increasing the number of faculty in the department would help boost the ranking of the department. Many in the faculty feel we are doing more with less than comparable departments.

D.2 Internal Rankings

As a member of the College of Science (COS), the quality or efficiency of the department is measured primarily using three variables: state expenditures on the department (State), ICR from research grant indirect costs, and student credit hours (SCH). These three variables and the total grant expenditures (a measure of the total grant income) for the department are given in Table 1. The total ICR to the University is reported rather than the ICR return to the COS, but they are of course proportional.

Item	FY11	FY12	FY13	FY14	FY15	FY16	FY17
State Expenditures (M$)	4.5	4.5	4.7	4.4	4.6	5.3	5.8
Student Credit Hours (khours)	13.5	14.1	14.5	13.6	15.3	15.5	14.9
ICR to UA (M$)	1.17	1.05	0.99	1.02	1.08	1.09	1.10
r ratio					0.88	0.83	0.90
Grant Expenditures (M$)	5.2	4.5	4.2	4.3	4.6	4.4	4.6
Faculty Size	27.3	24.3	26.5	26	27	28	28

Table 1: Physics department quality metrics used by the COS

The ratio r in Table 1 is a function of ICR and SCH in the numerator and State Expenditures in the denominator. There are a few other variables included (such as majors, number of degree completions, and temporary teaching (TA) budget) but they have modest impact. The definition has changed slightly since the implementation of Responsibility Centered Management (RCM), and is only reported since 2015. However a previous definition of the ratio r gave similar results. Typically the physics department falls in (the upper part) of the lower half of departments using this ratio. The departments of geosciences and ecology and evolutionary biology, with comparable faculty sizes, have efficiencies very similar to ours.

The total grant revenue divided by the number faculty in 2017 is $164k. A small number of faculty were without funding at that time. If we make an estimate using only funded faculty in the denominator, then the average funding per faculty is roughly $200k. This is a healthy funding level for an individual investigator award in many subfields of physics. Substantial boosting of the department's total grant revenue through increases in individual funding is unlikely. Rather, the department must look beyond individual investigator awards to leadership in larger science centers or focused multi-university collaborations for significant additional revenue.

Another measure of the department's quality can be found in the research awards garnered by faculty. Many faculty have received National Science Foundation (NSF) Presidential Young Investigator or CAREER awards, DOE Outstanding Junior Investigator awards or US Department of Energy (DOE) CAREER awards, as summarized in Table 2. These are among the most meritorious awards for young faculty. This table only lists relatively recent awardees. Likewise, several faculty have been named Sloan Fellows or received Research Innovation Awards from Research Corporation. Many faculty are Fellows of the American Physical Society.

Name	Award	Year
John Schaibley	DURIP Award	2018
Sam Gralla	NSF CAREER Award	2018
John Schaibley	AFOSR YIP	2017
Eduardo Rozo	DOE CAREER Award	2016
Weigang Wang	NSF CAREER Award	2014
Brian LeRoy	NSF CAREER Award	2010
Arvinder Sandhu	NSF CAREER Award	2010
Sean Fleming	DOE OJI Award	2005
Bira van Kolck	DOE OJI Award	2001
Srin Manne	NSF CAREER Award	2001

Table 2: Faculty awarded NSF, DOE or other young faculty awards since 2000

Locally, a number of faculty have been recognized by the UA for their research accomplishments. A list of relatively recent awardees is given in Table 3. Being named a Galileo Circle Fellow is one of the highest honors the the COS can bestow.

Name	Award	Year
Arvinder Sandhu	UA Distinguished Scholar Award	2017
Elliott Cheu	UA Distinguished Professor designation	2016
Shufeng Zhang	UA Henry and Phyllis Koffler Research and Scholarship Prize	2016
Sumit Mazumdar	UA Henry and Phyllis Koffler Research and Scholarship Prize	2006
Fulvio Melia	Galileo Circle Fellow	2005

Table 3: Faculty who have received UA research awards since 2000

A few faculty have received international and national awards. A list of relatively recent awardees is given in Table 4

Name	Award	Year
Sam Gralla	2018 IUPAP Young Scientist Prize in General Relativity and Gravitation	2018
Eduardo Rozo	Alfred P. Sloan Fellowship	2016
Stefan Meinel	Kenneth G. Wilson Award	2015
Bira van Kolck	Langevin Prize of the French Physical Society	2015
Fulvio Melia	Australia Sir Thomas Lyle Fellow Award	2008
Fulvio Melia	Erskine Fellowship (New Zealand) for Distinguished International Visitors	2007
Koen Visscher	Bechman Young Investigator	2001
Fulvio Melia	Miegunyah Fellow (Australia) for Distinguished Fundamental Researcher	2001
Charles Stafford	ABB Prize of the Swiss Physical Society Prize	2000

Table 4: Faculty who have received national or international research awards since 2000

Brian Schmidt, a UA physics department alumnus, shared the 2011 Nobel Prize in Physics.

D.3 Unit Peer Institutions

The department identified five aspirational peers. Three of the peer departments are from the ABOR list of peer universities: U.C. Davis, University of Florida, and University of North Carolina (UNC). Many other departments from the ABOR list of peer universities have a significantly larger number of faculty in the physics (and sometimes physics and astronomy) department. The other two peer departments have the same rank as given by US News and World Report: Indiana University and Boston University.

While the department always seeks to improve using new ideas and programs from our peers, it must also be noted that many departments have unique features, making head-to-head comparison difficult. For example, a department might have an associated nuclear physics facility that is combined in complex ways with the physics department. Or there might be a university center with which the department collaborates significantly. Comparison in these cases must be thoughtful and probably limited.

Table 5 compares two statistics reflecting majors and completed degrees at UA and that at the peer universities. These numbers divided by the number of faculty are also given in the table. The data were taken from http://www.aip.org/statistics/reports/roster-physics-2016 and provide a snapshot of enrollments and completed degrees from 2016. The majors are defined in this instance as the sum of junior and senior undergraduate physics majors. The number of faculty is taken from (http://www.gradschoolshopper.com/gradschool), another AIP product using data from 2017.

The data show that the number of majors/faculty at UA is above average compared to our chosen peers. The number of completed degrees/faculty is average or slightly below compared to our peers. Establishing an Applied Physics major should increase both the number of majors and the completed degrees.

University	Faculty	Majors 3rd + 4th Yr	Completed Degrees	Majors Ratio	Degrees Ratio
Arizona	32	96	22	3.0	0.7
Boston U	43	68	16	1.6	0.4
UNC Chapel Hill	31	100	42	3.2	1.4
UC Davis	56	161	47	2.9	0.8
U Florida	39	85	15	2.2	0.4
Indiana U	36	83	26	2.3	0.7

Table 5: Comparison of statistics reflecting the undergraduate program at UA and peer departments

Table 6 compares four statistics reflecting the Ph.D. program at UA and that at the peer universities. The numbers of graduate students and completed Ph.D.'s in 2012-2017 divided by the number of faculty are also given in the table. The information is taken from (http://www.gradschoolshopper.com/gradschool), using data from 2017.

University	Faculty	Grads	Completed Ph.D. 2012-2017	Applications	Enrolled	Grads Ratio	Completed Ratio
Arizona	32	95	59	170	26	2.9	1.8
Boston U	43	81	73	363	9	1.9	1.7
UNC Chapel Hill	31	81	ND	156	15	2.6	ND
UC Davis	56	162	47	465	40	2.9	1.7
U Florida	39	123	125	230	17	3.2	3.2
Indiana U	36	105	49	163	12	2.9	1.4

Table 6: Comparison of statistics reflecting the graduate program at UA and peer departments

The data show that the number of graduate students / faculty is slightly above average and the number of completed degrees per faculty is very slightly below the average of our selected peers. Enrollment of 26 graduate students at UA was an anomaly for 2016 so the number of enrolled grad students per faculty is above average. More often this ratio would be closer to the peer average.

Table 7 compares three statistics reflecting the research program at UA with those at the peer universities. The number of grants, department research budget, and number of postdocs divided by the number of faculty are also given in the table. The data are taken from (http://www.gradschoolshopper.com/gradschool), using data from 2016 academic year. The number of grants at UA is low compared to our peer departments according to these data. Both the research grants divided by the number of faculty and the number of postdocs per faculty are also below the peer department average. As previously mentioned, by increasing the number of faculty in key areas such as experimental AMO and experimental condensed matter, the department would hope to better compete for leadership roles in the creation of national research centers.

University	Faculty	Number of of Grants	Research Budget $M	Postdocs	Number of Grants Ratio	Research Budget Ratio	Postdocs Ratio
Arizona	32	30	4.5	9	0.94	0.14	0.28
Boston U	43	81	6.3	16	1.88	0.15	0.37
UNC Chapel Hill	31	94	8.1	13	3.03	0.26	0.42
UC Davis	56	159	9.4	26	2.84	0.17	0.46
U Florida	39	55	10.4	30	1.41	0.27	0.77
Indiana U	36	ND	9.1	8	ND	0.25	0.22

Table 7: Comparison of statistics reflecting the research program at UA and peer departments

Another set of comparison data was generated by the office of University Analytics and Institutional Research. The data are collected from Academic Analytics, a data provider for research universities. The data are collected from 2012-2016. The same five peer departments were used as above.

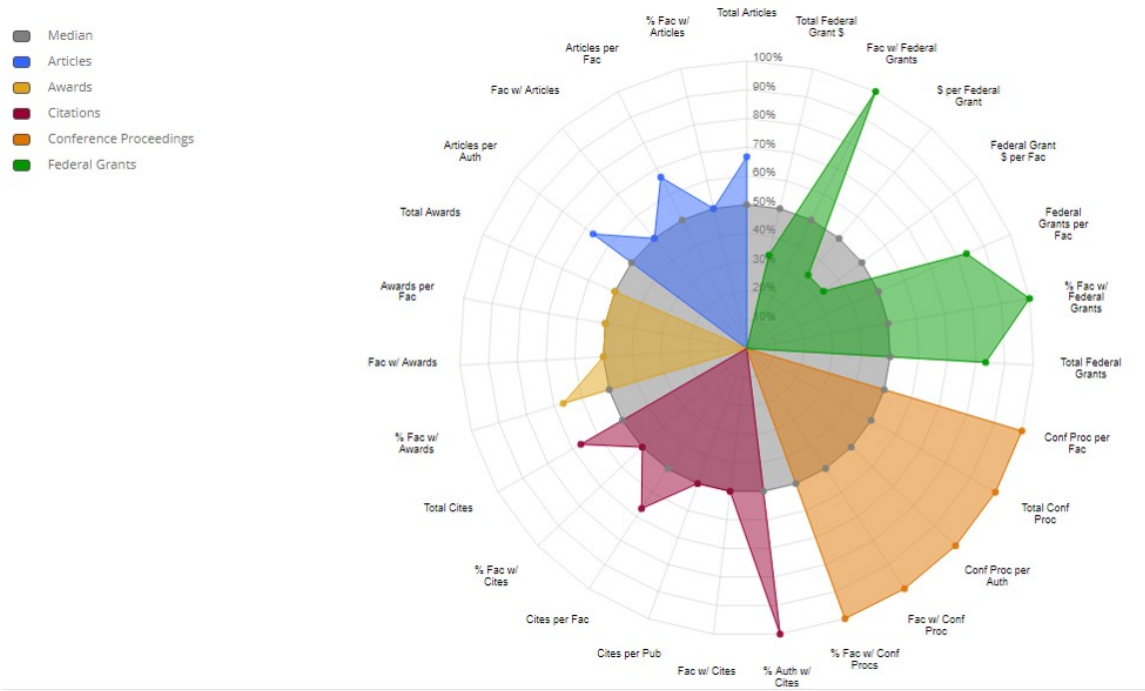

Figure 1: Radar chart from Academic Analytics.

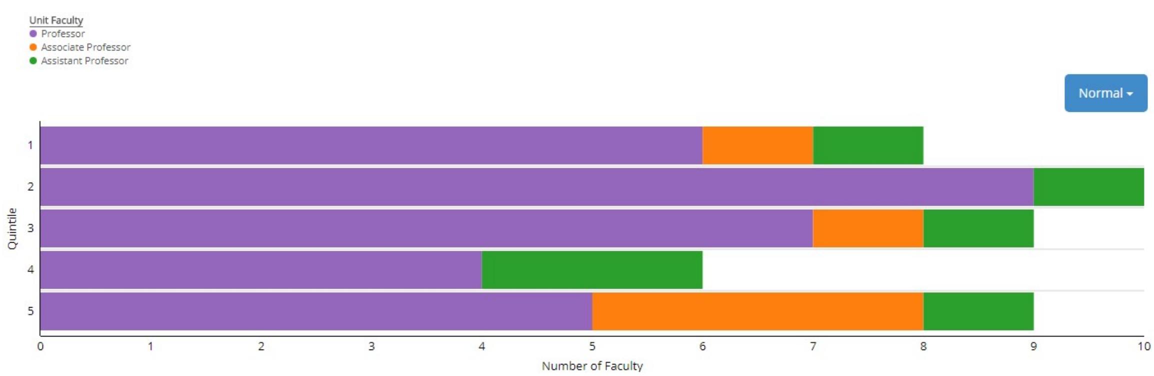

Figure 2: Quintile chart from Academic Analytics.

The data are given in Figures 1 and 2 and the raw data are in Table 3. For technical reasons, Indiana University was not included in the median calculations used in the radar and quintile charts, however the raw data is given in the table.

The radar chart shows that UA is performing at or better than the median values of performance metrics of the five peers for most metrics. This conclusion is based on the fact that the colored petals are at or outside of the 50% median.

Looking at the raw data, one can see that in most metrics, UA is doing slightly better than our peer departments. The UA physics department is below average in total federal grant dollars, dollars per federal grant and federal grant dollars per faculty. This conclusion agrees with that from gradschoolshopper.com. The department hiring plan to increase the number of experimentalists in the department will help improve these metrics.

For the quintile plot, there were about 250 faculty total in the five peer departments. The data show that the UA department is average compared to the peer departments in the sense that we have approximately

Release	AAD2016.03.833	AAD2016.03.833	AAD2016.03.833	AAD2016.03.833	AAD2016.03.833	AAD2016.03.833	AAD2016.03.833	AAD2016.03.833
Discipline	Physics, General	Physics, General	Physics, General	Physics, General	Physics, General	Physics, General	Physics, General	Physics, General
Discipline_id	140	140	140	140	140	140	140	140
Institution	Boston University	Indiana University -	University of Arizona, Th	University of California, Davis	University of Florida	University of North Carolina at	Indiana University - B	Indiana University - Blo
Institution_id	24	96	247	252	273	316	96	96
Unit	Physics	Physics	Physics	Physics	Physics	Physics and Astronomy	Chemical Physics (Ph	Mathematical Physics (
Unit_id	235	1506	4284	4504	5195	6661	15443	15445
Faculty	46	36	42	48	43	37	2	3
% of Faculty With an Article	0.956521739	1	0.976190476	1	0.976744186	1	1	1
Articles Per Author	28.1	25.6	24.8	25.5	22.4	12.6	7.5	18.7
Articles Per Faculty	26.8	25.6	24.2	25.5	21.9	12.6	7.5	18.7
Number Faculty With Articles	44	36	41	48	42	37	2	3
Total Number Articles	1235	922	1015	1225	942	468	15	56
% Faculty With an Award	0.673913043	0.638888889	0.666666667	0.645833333	0.744186047	0.540540541	0.5	0.666666667
Awards Per Faculty	1.5	0.9	1.1	1.2	1.3	0.8	0.5	1.7
Number Faculty With an Award	31	23	28	31	32	20	1	2
Total Awards	69	34	47	58	57	31	1	5
% of Faculty With Book	0.217391304	0.222222222	0.142857143	0.083333333	0.11627907	0.108108108	0	0.666666667
Book Publications per Faculty	0.4	0.2	0.3	0.1	0.2	0.2	0	0.7
Number Faculty With Book	10	8	6	4	5	4	0	2
Total Number Books	17	8	12	5	8	7	0	2
% of Authors With Citation	1	0.972222222	1	1	1	1	1	1
% of Faculty With Citation	0.956521739	0.972222222	0.976190476	1	0.976744186	1	1	1
Citations Per Article	31.3	27.6	26.1	31.7	27.8	15.9	5.5	13.5
Citations Per Faculty	1113.6	922.2	824.4	1052.2	799	248.7	52.5	315.7
Number Faculty With Citation	44	35	41	48	42	37	2	3
Total Number Citations	51225	33201	34625	50507	34358	9203	105	947
% of Faculty with Conf Proc	0.260869565	0.444444444	0.571428571	0.270833333	0.488372093	0.540540541	0.5	0.333333333
Conf Proc Per Author	2.5	3.9	5.6	2.5	2.7	4.1	2	1
Conf Proc Per Faculty	0.7	1.7	3.2	0.7	1.3	2.2	1	0.3
Number Faculty With Conf Proc	12	16	24	13	21	20	1	1
Total Number Conf Proc	30	62	134	32	57	82	2	1
% Faculty With Grant	0.652173913	0.5	0.761904762	0.5625	0.674418605	0.675675676	0.5	0.333333333
Dollars Per Grant	251959	321497.1	136541.5	211370.1	191740	199480.3	85452.5	56592.5
Grant Dollars Per Faculty	356029.1	473315.2	234071.1	273019.8	410234.5	339655.7	85452.5	75456.7
Grants Per Faculty	1.4	1.5	1.7	1.3	2.1	1.7	1	1.3
Number Faculty With Grant	30	18	32	27	29	25	1	1
Total Grant Dollars	16377337	17039347	9830987	13104948	17640084	12567261	170905	226370
Total Number Grants	65	53	72	62	92	63	2	4
SRI Percentile	77.77777778	44.44444444	77.77777778	88.88888889	100	33.33333333	22.22222222	77.77777778
SRI Rank	3	6	3	2	1	7	8	3
SRI	0	-0.1	0	0.1	0.2	-0.3	-1.1	0

equal numbers of our faculty in all quintiles. The department does not have relatively more overperformers or underperformers than our peer departments.

E Faculty

E.1 Research

The faculty in the physics department is actively engaged in a wide range of leading-edge research areas. Some faculty members work in several areas and some carry out interdisciplinary research that involves other fields besides physics. For convenience, the list of 28 current faculty members, their rank, and their primary research field is given in Table 8.

Many faculty members are acknowledged leaders of their fields. For example, our high-energy and cosmology experimentalists take on leadership roles in their large collaborations at the LHC (ATLAS), the Large Synoptic Survey Telescope (LSST), the Dark Energy Survey, the mid-scale Dark Energy Spectroscopic Instrument, and the Sanford Underground Research Facility (Deep Underground Neutrino Experiment (DUNE)). Among other roles, Rutherfoord has been deputy chair and then chair of the US ATLAS Institute Board, Rozo is member of the LSST Dark Energy Science Collaboration (DESC) Council, and Sarcevic is member of the DUNE Institutional Board.

Many awards have been bestowed on the faculty. A list of awards received over the last seven years include many College of Science (COS) and university awards, several early-career awards from the Air Force Office of Science Research (AFOSR), the DOE, the NSF, the Science Foundation of Arizona (SFAz), and the Sloan Foundation, and international prizes from the Chinese Academy of Sciences (CAS) and the French Physical Society (SFP). In addition, three faculty members became APS fellows during the reporting period.

A list of recent faculty awards is given in Table 9.

A summary of the current research areas in the department follows.

- Theoretical Astrophysics, Cosmology and Gravitation (Gralla, Melia)

  This group encompasses some of the highest profile research on campus dealing with topics in gravitational physics, theoretical astrophysics, and cosmology. They study a broad range of phenomena, from gravitational-wave sources and signatures, to the high-energy environments of compact objects (neutron stars and black holes), to the formation of galaxies and large-scale structure, to the nature of cosmic expansion and the particle astrophysics of these environments, including the early Universe. The faculty and students in this group have played a leading role in developing a theoretical understanding of supermassive black holes, especially creating and developing the idea of imaging the shadow of the object at the center of our galaxy, known as Sgr A*, with the Event Horizon Telescope (EHT). The group is currently leveraging ideas from string theory to study the astrophysics of rapidly rotating black holes, providing new techniques for this previously intractable regime of parameter space. This is producing striking theoretical predictions of unique "smoking gun" signatures observable with current and upcoming detectors, including Laser Interferometer Gravitational-Wave Observatory (LIGO) and Laser Interferometer Space Antenna (LISA), as well as EHT. Ongoing work also includes the identification of signatures at other wavelengths (e.g., from tidal disruption events or dark-matter annihilation), enabling the discovery of rapidly rotating black holes in nature.

  The quality of this work is recognized by numerous awards. Most notably, the group has received over seven prestigious graduate fellowships from NSF and National Aeronautics and Space Administration (NASA). Many of the group's students receive awards, such as the Trumpler award, and go on to high profile academic careers at various universities around the world, such as Leicester and Amsterdam. The faculty have themselves been recognized with distinguished national and international awards, including Sloan Fellowships, NSF CAREER Awards, and numerous distinguished visiting professorships in Europe, Australasia and China. Melia is an American Physical Society (APS) Fellow. They sit on several influential editorial and advising boards, and are heavily involved in high-level outreach activity. The publication of over 6 books, mostly directed to the general public, are used as a basis for delivering numerous public lectures at venues such as the Smithsonian in Washington and the Rome Science Festival. The group is closely tied to the UA Theoretical Astrophysics Program (TAP), which

Name	Rank	Research Area
Cheu, Elliott	Professor	Particle experiment
Cronin, Alexander	Professor	Atomic, Molecular, and Optical physics (AMO) experiment
Dienes, Keith	Professor	Particle theory
Fleming, Sean	Professor	Nuclear theory
Gralla, Sam	Assistant Professor	Astro/Cosmo/Gravity theory
Johns, Kenneth	Professor	Particle experiment
Hassan, Mohammed	Assistant Professor	AMO experiment
Lebed, Andrei	Professor	Condensed-matter theory
LeRoy, Brian	Associate Professor	Condensed matter experiment
Manne, Srinivas	Associate Professor	Condensed matter experiment
Mazumdar, Sumitendra	Professor	Condensed-matter theory
Meinel, Stefan	Assistant Professor	Particle theory
Melia, Fulvio	Professor	Astro/Cosmo/Gravity theory
Rafelski, Johann	Professor	Strong-field theory
Rozo, Eduardo	Assistant Professor	Cosmology experiment
Rutherfoord, John	Professor	Particle experiment
Sandhu, Arvinder	Associate Professor	AMO experiment
Sarcevic, Ina	Professor	Particle theory
Schaibley, John	Assistant Professor	Condensed matter experiment
Stafford, Charles	Professor	Condensed matter theory
Su, Shufang	Professor	Particle theory
Toussaint, Doug	Professor	Particle theory
van Kolck, Ubirajara	Professor	Nuclear theory
Varnes, Erich	Professor	Particle experiment
Visscher, Koen	Associate Professor	Biophysics experiment
Wang, Weigang	Assistant Professor	Condensed matter experiment
Wolgemuth, Charles	Professor	Biophysics experiment
Zhang, Shufeng	Professor	Condensed matter theory

Table 8: List of tenured and tenure-track physics faculty

Name	Award	Date
Cheu	UA Distinguished Professor	2016
Cheu	UATeam Award for Excellence	2017
Cheu, Johns, Rutherfoord, Shupe, Varnes	UA COS Galileo Circle Dean's Award	2013
Cronin	UA Udall Center Fellowship	2015
Dienes	APS Fellow	2010
Gralla	UPAP Young Scientist Prize in General Relativity and Gravitation	2018
Gralla	NSF CAREER Award	2017
Lebed	APS Fellow	2014
LeRoy	NSF CAREER Award	2010
Mazumdar	APS Outstanding Referee	2011
Meinel	Kenneth G. Wilson Award	2015
Melia	AAP PROSE Award	2010
Melia	Amherst College Woodruff Simpson Chair	2012-14
Melia	CAS Distinguished Visiting Professor	2012-date
Melia	Sydney U Walter Stibbs Visiting Chair	2014
Rozo	Cottrell Scholar	2018
Rozo	DOE Early Career Award	2016
Rozo	Sloan Fellow	2016
Sandhu	NSF CAREER Award	2010
Sandhu	UA Distinguished Scholar Award	2017
Schaibley	DURIP Award	2018
Schaibley	AFOSR Young Investigator Award	2016
Schaibley	SFAz Bisgrove Scholar Award	2017
Schaibley	SFAz AFOSR YIP (Air Force)	2017
Su	APS Fellow	2014
van Kolck	*Ann. Phys.* Outstanding Reviewer	2014
van Kolck	French Physical Society (SFP) Paul Langevin Prize	2015
Wang	NSF CAREER Award	2016
Wolgemuth	*Biophys. J.* Best of 2016 article	2016
Zhang	CAS Hai-O Award	2012
Zhang	UA Koffler Award for Research	2016

Table 9: Faculty awards since 2010

brings together astrophysicists from astronomy, planetary sciences, and physics and is routinely ranked in the top handful of such programs in the country.

- Experimental Atomic, Molecular, and Optical (AMO) Physics (Cronin, Hassan, Sandhu)

  Faculty in experimental AMO physics are pushing the boundaries of attosecond science, x-ray spectroscopy, electron microscopy, and matter-wave interferometry. The field of ultrafast science offers extraordinary tools for measurement, manipulation, and control of dynamical processes in atoms, molecules, and nanomaterials. The department's laser groups have expertise in the generation and application of attosecond pulses in the extreme-ultraviolet regime, to probe electron dynamics on their natural time scale. This research has provided groundbreaking insights into non-adiabatic dynamics in molecules, light-induced modification and control of electronic structure, and electronic coupling/correlation driven dynamics in molecules and materials. Ongoing efforts aim to image the electron motion through electron microscopy with sub-femtosecond electron pulses, opening a new field of "attomicroscopy". Another significant direction is atom optics, where the group has pioneered techniques that exploit atomic and molecular wave interferometry for precision measurements of physical constants.

  AMO efforts in the physics department have extensive cross connections with related efforts in the College of Optical Sciences and the chemistry department, resulting in a very prominent and highly-ranked AMO program.

- Experimental Biophysics (Visscher, Wolgemuth)

  Biological physics examines living processes through the application of physical principles. Core-faculty research in the department focuses on cell motility, cellular biomechanics, single-molecule studies of gene expression, from transcription to translation by ribosomes, neuroscience, and imaging. A variety of experimental techniques including quantitative live-cell imaging, widefield and single-molecule fluorescence microscopy, and optical tweezers are employed to determine the role and effect of mechanical forces in molecular and cellular biological processes.

  Group members are leaders in the area of cellular motility. Their research has been highlighted in the press and in a paper chosen among the best of 2016 by *Biophys. J.* They have served in various editorial boards, and were among the founding members of the UA's Biological Physics Program (BPP), an interdisciplinary group that spans several traditional departments (chemistry and biochemistry, molecular and cellular biology, physics, and physiology). Currently there are 7 faculty members that form the primary core of the BPP (Brown, Visscher, Wolgemuth, Granzier, Harris, Tardiff, and Schwartz). The BPP holds a biweekly journal club and a few seminars per semester. In addition, the BPP co-organizes Biophest, a yearly joint meeting between biophysics researchers from UA and Arizona State University (ASU).

- Experimental Condensed-Matter Physics (LeRoy, Manne, Schaibley, Wang)

  The program in experimental condensed-matter physics studies the fundamental electronic and optical properties of materials and devices. Currently research in the group is focused on spintronic devices and two-dimensional materials such as graphene and transition metal dichalcogenides. These materials are probed with a variety of techniques from scanning probe microscopy to optical spectroscopy and electrical transport measurements. Recent highlights from the group include the use of boron nitride to improve and modify the electronic properties of graphene, the observation of interlayer excitons in transition metal dichalcogenide heterostructures, and voltage controlled coupling in magnetic tunnel junctions.

  Junior faculty in the group have recently been awarded an NSF CAREER Award and an AFOSR Young Investigator Award. Research in the group has been supported by funding from AFOSR, Army Research Office (ARO), Defense Advanced Research Projects Agency (DARPA), NSF, SFAz, and Semiconductor Research Corporation.

- Theoretical Condensed-Matter Physics (Lebed, Mazumdar, Stafford, Zhang)

  Theoretical condensed-matter research in the physics department covers broad areas such as strongly correlated materials physics, electronic structure, mesoscopic and nanoscale materials, superconductors, magnetism, and spintronics. Specific topics under study include novel organic semiconductors with applications to organic photovoltaics, unconventional organic and high-temperature superconductors, quantum transport in nanoscale conductors including molecular tunnel junctions, and magnetic and spin transport properties of nanomagnets. Recent highlights include the development of a full many-body theory of singlet fission within the area of organic photovoltaics, the proposed novel theory of charge order-superconductivity duality that appears to be fundamentally important in the field of correlated electron superconductivity, pioneering of temperature and voltage measurement in quantum systems far from equilibrium, the prediction of non-Fermi-liquid crossovers in quasi-1d conductors in a strong magnetic field, and the construction of magnonic transport theory for spintronic devices.

The group has had strong collaborations with the condensed-matter experimental group on the physics of low-dimensional materials such as graphene and its nanofragments, and magnetic tunnel junctions. Three members of the group are APS fellows and one has been a *Phys. Rev. Lett.* Divisional Associate Editor.

- Experimental Cosmology (Rozo)

  The group's research in experimental cosmology is primarily centered on using clusters of galaxies as probes of large-scale structure, though it has expanded to other large-scale structure probes. They use photometric survey data to stress-test the currently favored flat Lambda Cold Dark Matter (LCDM) model of cosmology. A significant amount of effort is spent on systematics mitigation for state-of-the-art cosmology experiments such as the Dark Energy Survey (DES) and the LSST. Recent highlights include: i) production of redmapper, the highest-quality photometric catalog to date; ii) production of redmagic, the sample of galaxies with highest-quality photometric redshifts in the DES; iii) a leading constraint on the Hubble constant from combining baryon acoustic-oscillation data, big-bang nucleosynthesis data, and DES data; iv) the world's leading constraint on the flat LCDM model from the abundance of DES galaxy clusters (to appear early 2018).

- Theoretical Nuclear Physics (Fleming, van Kolck)

  The nuclear theory group carries out internationally recognized research in nuclear physics using effective field theories (EFTs) of Quantum Chromodynamics (QCD). They invented Soft Collinear Effective Theory to describe the high-energy behavior of quarks and gluons, which they are currently applying to precision determinations of parton and transverse momentum-dependent distribution functions, and heavy quark fragmentation functions. They have made significant improvements to Heavy-Quark Effective Theory and Non-Relativistic QCD (in particular as applied to heavy quarkonium production), which they used to create an EFT for exotic hadronic states with hidden flavor, such as the X(3872). They have developed Nuclear EFTs (Chiral EFT, Pionless EFT, and Halo/Cluster EFT) to deduce the force among nucleons, relate it to lattice QCD, and predict the properties of light and halo nuclei. These EFTs have been used to analyze the low-energy implications of violations of fundamental symmetries such as time-reversal and baryon number, as well as extended to describe systems of cold, neutral atoms.

  The group's research has amassed about 17,000 citations and interfaces with that of the particle theory group on lattice QCD and physics beyond the Standard Model. Members of the nuclear theory group have a strong service record, such as participation in the advisory boards of the two most important centers for nuclear theory, the National Institute for Nuclear Theory and the European Center for Theoretical Nuclear Physics. Group members have received numerous awards including two DOE Outstanding Junior Investigator Awards, a Sloan Fellowship, and the Paul Langevin Prize of the French Physical Society. One of the members is APS Fellow.

- Theoretical Particle Physics (Dienes, Meinel, Sarcevic, Su, Toussaint)

  Members of the particle physics theory group have spearheaded a number of major developments in the field. They have done pioneering work in ultrahigh-energy neutrino interactions and are involved in computational studies of strong interactions which are among the most challenging and sophisticated supercomputer calculations in all science. Members of the group have done important work relevant to current and future particle accelerators, and are leaders in efforts to develop and analyze physics beyond the Standard Model, including Higgs phenomenology, flavor physics, supersymmetry, string theories and theories with large extra spacetime dimensions. Members of our group are also expanding the connections between particle physics and astrophysics by probing the properties of dark matter using cosmic neutrinos, by exploring new methods of dark-matter detection, and by developing new dark-matter scenarios beyond the Weakly Interacting Massive Particle (WIMP) paradigm, including a proposal for Dynamical Dark Matter (DDM), which has attracted much attention. Members of the group are also exploring the implications of new particle physics ideas for early-universe cosmology.

The particle theory group benefits from close connections to the local theoretical nuclear physics group as well as local astrophysics and applied mathematics faculty. One member of the group is currently on leave, serving as the Director of the Particle Theory and Cosmology Programs at the NSF, but maintains full research activity in Arizona, including the training of graduate students and postdocs. The four senior members of the group are APS Fellows and one has been a Humboldt Fellow. All have organized and hosted major international meetings in Arizona (such as SUSY 2003, LATTICE 2006, etc.), and two have served as Chairs of the Four Corners Section of the American Physical Society. The junior group member has received the Kenneth G. Wilson Award for Excellence in Lattice Field Theory for his work on the physics of the bottom quark.

- Experimental Particle Physics (Cheu, Johns, Rutherfoord, Varnes)

  The primary focus of this group is the ATLAS experiment at the CERN LHC. The group is pursuing several searches for physics beyond the Standard Model, including searches for vector-like quarks, for resonances that decay into top quark pairs, and for DDM, a new approach to dark matter physics proposed by Dienes, a member of the UA particle theory group. Group members take leadership positions for these searches. This work has resulted in several publications and Ph.D. theses based on ATLAS data recorded between 2012 and 2017, with analysis of the more-recent data samples ongoing. The group also makes significant contributions to the core software used to reconstruct ATLAS events, particularly through the work of research scientist Peter Loch, a leading expert on reconstructing jets and missing transverse momentum. Loch received the UA College of Science Copernicus Award in 2016.

  In addition, the group has a long history of contributions to the design and construction of the ATLAS detector and its electronics. This is highlighted by the concept for, and partial construction of, the forward calorimeter. This calorimeter uses a novel design that has proven to be highly successful. Presently we have responsibility for several large electronics projects for the Phase 1 upgrade of ATLAS, including the construction of front-end electronics for Micromegas detectors in the New Small Wheel, construction of new electronics for the forward calorimeter, and development of significant firmware for the Liquid Argon calorimeter trigger . For the Phase 2 upgrade several years in the future, we have responsibilities for firmware for the Liquid Argon calorimeter readout electronics and hardware and hardware and firmware for electronics related to the track trigger upgrade.

- Theoretical Strong Fields (Rafelski)

  A new group develops research on strong fields, an emerging field that combines the physics of high-Z atoms and high-Z nuclear collisions at modest to relativistic energies with fundamental physical phenomena made accessible by ultra-intense lasers. This effort aligns well with the evaluation presented by the National Academies study released in December 2017, which recommends that DOE lead the development of a coordinated national research strategy, including investment in at least one new large-scale facility co-located with a major particle accelerator infrastructure. At UA this research is an outgrowth of the group's flagship contribution to the field of nuclear science, strangeness signatures of a quark-gluon plasma.

  The group is very active despite its limited size, hosting 6 graduate students, most of whom have already completed all examinations and are working towards their Ph.D.'s.

- Accelerator Mass Spectrometer Laboratory (Director Greg Hodgins, Geosciences Professor Anthony Jull, research scientists Warren Beck and George Burr (until 2015))

  The Arizona Accelerator Mass Spectrometer (AMS) facility conducts research on extremely rare and low abundance cosmogenic radioisotopes such as ^{14}C, ^{10}Be, ^{26}Al, and ^{129}I using a 3.0 MV accelerator mass spectrometer designed for this express purpose. The facility, commissioned in 1981 as an NSF center for isotope research, has now made more than 100,000 such measurements for scientists at our facility and elsewhere around the US and the world. Applications for such measurements are wide ranging and include such diverse topics as archeology, climate dynamics, solar physics, geomagnetic field variations, ocean and atmospheric dynamics, geomorphology, glaciology, cosmic-ray studies, extraterrestrial samples (lunar samples and meteorites) and forensic science. Scientists at our facility have played important roles in many of these fields, such as development of an entirely new paleo-rainfall proxy using ^{10}Be, determining the origins of organic carbon in Martian meteorites, or helping to establish the INTCAL calendar age model for the radiocarbon timescale, a product that is used extensively in archeology. Collectively their works have been cited over 23,000 times.

E.2 External Funding

The faculty's research is funded by an array of external sources that range from the SFAz to RIKEN in Japan, with the bulk coming from the DOE and the NSF. Significant amounts are provided also by other federal agencies such as the ARO, the AFOSR, the NASA, and the National Institutes of Health (NIH). As mentioned elsewhere in this report, the total grant revenue per faculty member was $164k in 2017. Table 10 summarizes the current grants and contracts received by the faculty. Pending grants are given in Table 11.

Another reflection of the creativity of the physics faculty is a number of devices invented in the pursuit of research. Granted and pending patents since the last APR can be found in Tables 12 and 13, respectively.

E.3 Participation in the Academic Profession

The physics faculty participates actively in all aspects of the academic profession: leadership in professional societies, organization of national and international meetings, editorial duties, reviewing of papers and grant proposals, and various forms of institutional advising.

Physics faculty members belong to one (APS) or more professional and/or honor societies (e.g. Biophysical Society, Optical Society of America (OSA), Sigma Xi Honor Society, American Association of University Professors). They are occasionally engaged in the management of these organizations, as shown for the reporting period in Table 14.

Physics faculty members regularly organize and advise stand-alone scientific meetings; a summary of participation in organizing (OC, IOC) and advisory (SAC, IAC) committees is presented in Table 15. Additionally, they routinely organize and/or chair sessions at large meetings such as the APS March Meeting (2012, 2016, 2017), the DAMOP meeting (2014, 2017), the Gordon Conference (2014), and CLEO (2016).

Many physics faculty have taken leadership roles also as editors of journals or book series, as shown in Table 16. Because of their standing, our faculty members take on a heavy load of refereeing for high-impact journals, including ApJ, ApJL, AP, MNRAS, Nature, Nature Cell Bio., Nature Comm., Nature Phot., Nature Phys., NPA, PLB, PNAS, PRB, PRC, PRD, PRL, PRX, RMP, Science, and many others. They also review grant proposals for national funding agencies such as ARO, DOE, NASA, and NSF, as well as international ones such as DFG, ERC and NSERC. A list of funding panels they have participated in is given in Table 17. Note that our faculty contributes significantly to the funding agencies in the form of personnel: for the last few years Cronin and Dienes have been Program Directors in the Physics Division of the NSF for, respectively, Experimental Atomic, Molecular and Optical Physics plus Quantum Information Science, and Theoretical High-Energy Physics, Astrophysics and Cosmology. Moreover, Dienes served in 2014 as Program Manager for Theoretical High-Energy Physics in the DOE Office of Science. In these roles our faculty take a critical position of leadership for the entire community, directly shaping the future of their fields.

Finally, the faculty provides advice on all sorts of scientific issues for a variety of institutions. Some faculty serve in short-term committees — for example, search, Habilitation and Ph.D. committees in institutions in Europe such as Aalto University, the University of Paris, and the University of Groningen. Some of the major advising roles are listed in Table 18.

PI	Faculty	Source	Amount	Period
Cronin/Sandhu	Cronin/Sandhu	NSF	$464,041	2013-18
Fleming	Fleming	DOE/MIT	$81,000	2016-20
Fleming	Fleming, van Kolck	DOE	$570,000	2014-17
Fleming	Fleming, van Kolck	DOE	$370,000	2018-20
Gralla	Gralla	NSF	$150,000	2015-18
Johns	Cheu, Johns, Rutherfoord, Varnes	DOE	$3,590,000	2016-18
Johns	Dienes, Meinel, Toussaint, Sarcevic, Su			
Johns	Cheu	DOE	$50,000	2016
Johns	Johns	DOE/US ATLAS	$1,375,656	2015,16,17
Johns	Cheu, Johns, Varnes	NSF	$15,316	2017-18
LeRoy	LeRoy	ARO	$389,802	2014-18
LeRoy	LeRoy	NSF	$265,000	2016-19
LeRoy	LeRoy	NSF	$427,127	2017-20
Manne	Manne	NSF	$399,900	2015-18
Meinel	Meinel	RIKEN	$405,090	2014-19
Meinel	Meinel	NSF	$181,799	2015-18
Rozo	Rozo	DOE	$750,000	2016-20
Rozo	Rozo	NASA/Stanford	$34,501	2018-19
Rozo	Rozo	Sloan	$50,000	2016-17
Rutherfoord	Rutherfoord	DOE/US ATLAS	$746,547	2015,16,17
Sandhu	Sandhu	ARO/Berkeley	$835,874	2014-19
Sandhu	Sandhu	DOE	$449,500	2017-20
Sandhu	Sandhu	NSF	$321,801	2015-18
Schaibley	Schaibley	AFOSR	$360,000	2017-20
Schaibley	Schaibley	SFAz	$200,000	2017-19
Schaibley	Schaibley + 1 external	NSF	$400,000	2017-20
Schaibley	Schaibley, LeRoy	AFOSR	$300,000	2017-19
	+ 1 external			
Stafford	Stafford	DOE	$345,000	2017-20
Wang	Wang	NSF	$526,000	2016-21
Wolgemuth	Wolgemuth	NSF	$435,000	2014-18
Wolgemuth	Wolgemuth	NIH/Johns Hopkins	$248,670	2016-20
Zega (LPL-UA)	Wang + 3 external	NSF	$1,500,000	2015-18
Zhang	Zhang	NSF	$308,000	2014-18
Zhang	Zhang	NSF	$300,000	2017-20

Table 10: Current grants and contracts. In the case of external PIs or subcontracts, the awarded institution is listed under "Source", "PI" denotes the responsible local faculty member, and "Amount" refers to the physics department share

PI	Faculty	Source	Amount	Period
Gralla	Gralla	NSF	$400,000	2018-23
Hassan	Hassan	NSF	$392,387	2018-21
LeRoy	LeRoy, Schaibley	ARO	$390,182	2017-20
LeRoy	LeRoy	ARO	$100,634	2017-18
Manne	Manne	NSF	$420,900	2018-21
Mazumdar	Mazumdar	NSF	$478,522	2018-21
Mazumdar	Mazumdar	DOE	$485,000	2018-21
Schaibley	Schaibley	NSF CAREER	$749,329	2018-23
Schaibley	Schaibley	AFOSR	$129,331	2018-19
Wang	Wang, Zhang	NSF	$569,581	2018-21
Wang	Wang	DARPA/Minnesota	$833,917	2018-21
Wolgemuth	Wolgemuth	NSF	$586,364	2018-21
Wolgemuth	Wolgemuth	NSF	$324,245	2018-21
Wolgemuth	Wolgemuth	NSF+NIGMS	$993,158	2018-22

Table 11: Pending grants

Faculty	Device	US Patent No.	Year
Mazumdar, Stafford	Quantum Interference Effect Transistor	7,786,472	2010
Stafford	Nanoscale Variable Resistor/	8,492,231	2013
	Electromechanical Transistor	9,406,789	2016
Wang	Metal-Based Nonvolatile	62/301,771	2015
	Field-Effect Transistors		
Wang	Voltage-Controlled Magnetic Devices	14/885.609	2016

Table 12: Granted patents since 2010

Faculty	Device	Application No.	Year
Cronin	Solar Irradiance Measurement System and Weather Model	122170.00064/UA13-052US	2013
Wang	Perpendicular Magnetic Tunnel Junction with High Thermal Stability	15/633,653	2016
Wang	Magnetic Tunnel Junctions with Voltage Tunable Interlayer Coupling for Memory and Sensor Applications	15/720,399	2017

Table 13: Pending patents

Name	Role	Society	Years
Hassan	Executive Member	OSA-OU	2016-date
Su	Chair Line	APS-4CS	2011-13
Su	Publications Oversight Committee Member, Chair	APS	2014-17
Su	Sakurai Prize Committee Vice-Chair	APS	2017
van Kolck	Chair Line	APS-GFB	2008-12
van Kolck	Nominating Committee Chair	APS-GFB	2011
Zhang	Executive Member	APS-GMAG	2010-13

Table 14: Faculty leadership in professional societies since 2010

Name	Role	Meeting	Year
Cronin	SAC	Frontiers of Matterwave Optics Conf.	2016
Fleming	OC	APS Topical Group on Hadronic Physics Work.	2017
Dienes	Chair	Work. on Probing Non-Minimal Dark Sectors	2014
Dienes	Chair	Work. on Tying Particles and Strings to the Cosmos	2017
Dienes	IAC	Intl. Conf. on SUSY and Unification of Fund. Int.	2010-18
Lebed	IAC	Int. Symp. on Crystalline Organic Metals, Superconductors and Magnets	2011/13/15/17
Mazumdar	IAC, OC	Int. Conf. on the Science and Technology of Synthetic Metals	2010/12/14/16 /18
Mazumdar	IAC, OC	Int. Conf. on Optical Probes of Conjugated Polymers	2011/13/15/17
Mazumdar	IAC, OC	Int. Conf. on Crystalline Organic Materials	2015/17
Meinel	Chair	Int. Work. on Multi-Hadron and Nonlocal Matrix Elements in Lattice QCD	2015
Sandhu	OC	APS Four Corners Meet.	2011
Sandhu	OC	Multi-University Research Initiative Meet.	2016
Sandhu	OC	ITAMP/B2 Winter School on Quantum Information	2017
Sandhu	OC	OSA's Conf. on Lasers and Electro-Optics	2017/18
Sarcevic	OC	Int'l Conf. on Particle Physics and Astrophysics	2011/13-17
Sarcevic	OC	QCD Workshop	2010/12/14/16/18
Sarcevic	OC	Advanced Work. on Physics of Atmospheric Neutrinos	2018
Sarcevic	OC	Int'l Work. on Neutrino Astrophysics and Fundamental Properties	2015
Stafford	OC	APS Four Corners Meet.	2017
Su	IAC	Charged Higgs Work.	2016
van Kolck	OC	ECT* Work. on The Limits of Existence of Light Nuclei	2010
van Kolck	OC	FUSTIPEN Topical Meet. on Effective Field Theories for Nuclear-Structure Studies	2011
van Kolck	OC	ESNT Work. on Nuclear Forces From Effective Field Theory	2013
van Kolck	OC	ICTP-SAIFR School on Non-Perturbative QCD	2013
van Kolck	OC	ESNT Work. on Effective Field Theory of Nuclear Forces and the Many-Body Problem	2014
van Kolck	OC	ECT* Work. on Future Directions in the Physics of Nuclei at Low Energies	2014
van Kolck	OC	IIP Work. on Weakly Bound Exotic Nuclei	2015
van Kolck	OC	ICTP-SAIFR School on Effective Field Theories Across Length Scales	2016
van Kolck	OC	INT Prog. on Nuclear Physics from Lattice QCD	2016
van Kolck	OC	ECT* Work. on Baryons over Antibaryons	2016
van Kolck	OC	Rencontre du Vietnam on High-Sensitivity Experiments Beyond the Standard Model	2016
van Kolck	OC	Lorentz Work. on Matter over Antimatter	2017
van Kolck	IAC, OC	Int. Conf. on Few-Body Problems in Physics	2012/18
van Kolck	IAC	Pan-American Advanced Studies Inst. on Rare Isotopes	2010
van Kolck	IAC	Int. Conf. on Nucleus-Nucleus Collisions	2012/15
van Kolck	IAC	Int. Work. on Chiral Dynamics	2012/15/18
van Kolck	IAC	Int. Symp. on Chiral Symmetry in Hadrons and Nuclei	2013
van Kolck	IAC	European Nuclear Physics Conf.	2015
van Kolck	IAC	Int. Spring Seminar on Nuclear Physics	2017
van Kolck	IOC	Latin-American Symp. on Nuclear Physics and Applications	2011

Table 15: Faculty participation in conference organization

Name	Role	Venue	Years
LeRoy	Editorial Board Member	*Sci. Rep.*	2012-date
LeRoy	Associate Editor	*APL Mater.*	2013-date
Melia	Chief Editor	Theoretical Astrophysics Series, U of Chicago Press	2005-date
Sandhu	Editorial Board Member	*J. Las. Opt. Phot.*	2014-2017
Stafford	Review Editor	*Front. Phys.*	2013-date
Su	Editorial Board Member	*Sci. China Phys. Mech.*	2015-2018
Su	Editorial Board Member	*Chin. Phys. C*	2016-2020
van Kolck	Editorial Board Member	*Prog. Part. Nucl. Phys.*	2009-13
van Kolck	Editorial Board Member	*Phys. Rev. C*	2015-2017
Wolgemuth	Editorial Board Member	*Biophys. J.*	2010-16
Wolgemuth	Editorial Board Member	*Lett. in Biomath.*	2015-date
Wolgemuth	Editorial Board Member	*Math. Med. Biol.*	2015-date
Zhang	Advisory Board Member	*Magn. Lett.*	2008-date
Zhang	Advisory Associate Editor	*J. Magn. Magn. Mater.*	2012-date

Table 16: Faculty editorial service since 2010

Name	Panel	Agency	Year
Dienes	Chair of HEP Theory/Cosmology	NSF	2010-date
LeRoy	Condensed Matter Panel	NSF	2012/14/15/18
LeRoy	Electronic and Photonics Materials Panel	NSF	2016/18
LeRoy	Major Research Instrumentation Panel	NSF	2017
LeRoy	CAREER Panel	NSF	2106
LeRoy	Postdoctoral Fellowships Panel	NRC	2016
Manne	Research Experience for Undergraduates (REU) Program Evaluation	NSF	2016/17
Mazumdar	Materials Research	NSF	2012
Mazumdar	DMREF-Materials Research	NSF	2015/16/17
Melia	Consolidator	ERC	2015-21
Schaibley	Materials Research	NSF	2017
Stafford	Electrical, Communication, and Cyber Systems	NSF	2011
Sarcevic	Nuclear Theory	NSF	2014
Sarcevic	HUB Center	NSF	2016
Stafford	Materials Research Science and Engineering Center (MRSEC) (Minnesota)	NSF	2012
Stafford	Early Career	DOE	2012
Su	High-Energy Theory	NSF	2011-date
Su	Laboratories Theory Program Review	DOE	2014
Su	Cosmic Frontier Operating Experiment Review	DOE	2014
Wolgemuth	Modeling and Analysis of Biological Systems	NIH	2011/13
Wolgemuth	Living Systems	NSF	2011
Wolgemuth	Bacterial Pathogenesis	NIH	2013/14/16/17
Wolgemuth	DMS/NIGMS	NSF	2014/5/6
Wolgemuth	Mathematical Biology	NSF	2015
Wolgemuth	Bacterial Toxin Structure	NIH	2017
Zhang	Electrical, Communication, and Cyber Systems	NSF	2012/14
Zhang	Materials Research	NSF	2014
Zhang	MRSEC (Johns Hopkins)	NSF	2011

Table 17: Faculty participation in funding panels since 2010

Name	Committee	Institution	Years
Melia	Educational Council	MIT	2004-date
Melia	Scientific Committee	International Center for Relativistic Astrophysics	2005-date
Melia		National Research Council	2010-date
Su	Academic Committee	Center for Future High-Energy Physics, IHEP China	2013-date
Su	Advisory Board	Amherst Center for Fundamental Interactions	2014-date
Su	Program Advisory Committee	Jefferson Laboratory	2017-22
van Kolck	National Advisory Committee	Institute for Nuclear Theory	2014-17
van Kolck	Scientific Board	European Center for Theoretical Nuclear Physics	2014-date
Zhang	Advisory External Board	DOE-Energy Frontier Research Center, UC-Riverside	2015-date

Table 18: Faculty participation in advising boards and committees since 2010

E.4 Teaching

The typical teaching load for faculty in the physics department is one course per semester. This is similar to that for physics faculty at peer universities. Some faculty with additional administrative responsibilities (Associate Dean, head, associate head, and the Directors of Graduate and Undergraduate Studies) have reduced teaching responsibilities. A few faculty in the department with less productive research programs have increased teaching responsibilities.

It is the ethic in the physics department that all faculty take their teaching responsibilities seriously and continually strive for excellence. About a half of the faculty use some active learning methods in their teaching and this fraction is slowly growing.

Teaching quality is measured using peer observations and student course evaluations. Peer observations are carried out by the Teaching Performance and Innovation Committee. Items used in the evaluation are a slightly modified subset of the list of items in the Classroom Observation Tool developed by the Office of Instruction and Assessment (OIA) at UA. The items used for the peer observation are given in Appendix A. Twenty faculty have been observed thus far, some twice. For the first two years the observations are to provide constructive feedback to the instructors. It is planned in the future that the evaluations will become part of the annual department performance evaluation of faculty.

Student course evaluations provide another measure of teaching quality. The course evaluations are developed by the OIA. The questionnaires, which are filled out by students online, request students' overall ratings of the instructor, course, amount learned, course difficulty, assignments and class climate.

In Appendix B we show the summary Teacher-Course Evaluations (TCE)) for all physics department courses for spring 2017 and fall 2017. Names of instructors have been removed. The 100 or 200 level lab courses are taught by graduate Teaching Assistants and those courses are identified by the shorter number of questions compared to the lecture courses. The summaries shown give the average results on a scale of 5 (outstanding) to 1 (unacceptable).

The main conclusion from these reports is that the teaching in the physics department is effective and highly rated by the students. Most instructors received ratings between 3 and 4 (3 being "good").

Another measure of teaching quality can be found in a list of relatively recent teaching awards. Some of the teaching awards in the COS and University garnered by faculty are given in Table 19. Other faculty in the department have been finalists for these and other awards as well.

Name	Award	Year
Alex Cronin	Honors College Outstanding Professor	2009
Alex Cronin	Koffler Prize for Teaching	2009
Shawn Jackson	UA CLAS Distinguished Early Career Teaching	2010

Table 19: Physics faculty teaching awards since 2009

The following serves to satisfy the requirement of Appendix C, a Rubric for Self-Assessing Departmental Teaching Quality. There are four criteria listed below. For each, the self-assessment rating and rationale is given. The possible ratings are exemplary, developing and needs development.

- Expectations for Teaching Quality - Exemplary

  All faculty members are expected to provide high quality instruction to students. Quality teaching is evaluated by the Committee on Annual Performance Evaluation (CAPE). All faculty members are aware that a superior CAPE evaluation necessarily includes demonstrated high quality teaching. The CAPE committee reviews the previous three years of TCE evaluations as well as instructor comments on their self-assessment of teaching. The teaching evaluation by CAPE is given due weight in considerations of merit raises. In the future, peer evaluation of teaching will also likely become data evaluated by CAPE.

  Expectations for quality teaching are reinforced by the department head at faculty meetings throughout the academic year. Also, when the department head or Director of Undergraduate Studies (DUGS) becomes aware of possible unsatisfactory teaching performance via student feedback during the semester, the head has a discussion with class instructor, alerting him/her to potential problems. Thus department monitors teaching both formally (through CAPE) and informally (through discussions with the head).

- Support for Teaching Development - Developing

  The department provides some support for professional development towards high-quality teaching across the unit. However there is no standard process for this.

  Faculty, especially younger faculty, are made aware of opportunities to learn about effective teaching such as Faculty Learning Communities (FLC's) at UA. The DUGS has held a few physics-only FLC's and more regular meetings are planned for the future. In addition, the department head recommends new faculty for participation in the new faculty workshops organized by the American Association of Physics Teachers (AAPT). Several physics faculty have participated in these workshops. Their collective opinion is that the workshops were immensely useful in introducing them to active learning techniques.

  Nearly all of our introductory physics courses are taught using active learning methods. To facilitate this, the DUGS makes available to all instructors the course materials used in the small student group learning sessions. Course materials such as multiple choice voting questions are also made available. Similar course material is also made available by the DUGS for a small number of upper level physics courses.

  The head supports course improvement through teaching relief. Examples are the development of updated lab exercises for the introductory mechanics labs (PHYS 141 and PHYS 181) and the development of an online course for PHYS 102. The head supports workshop or conference attendance focused on the quality of teaching as was mentioned above in the example of new faculty workshops organized by AAPT.

- Evaluation of Teaching Development - Developing

  As mentioned, the annual faculty performance evaluation by the CAPE committee includes examination of the previous three years of TCE scores and self-assessment of teaching provided by the faculty member. Peer evaluation of teaching by the Teaching Evaluation and Innovation Committee is regularly carried out. Over half of the faculty have been observed with several faculty observed twice. Presently the results of the teaching observation are shared with the instructor along with constructive suggestions for teaching improvement. We expect to observe the remaining faculty by the end of the

Arrivals	Departures	P&T Reviews	Promotions
7	7	8	8

Table 20: Summary of physics faculty arrivals and departures since the last APR

Name	Arrival Year	Program
Weigang Wang	2012	Experimental Condensed Matter
Charles Wolgemuth	2012	Experimental Biophysics
Stefan Meinel	2014	Theoretical Particle Physics
Eduardo Rozo	2014	Experimental Cosmology
Sam Gralla	2015	Theoretical Astro/Cosmo/Gravity
John Schaibley	2016	Experimental Condensed Matter
Mohammed Hassan	2017	Experimental AMO

Table 21: Physics faculty hires since the previous APR

Spring 2018 semester. Tenure-track faculty will be peer observed every semester and given constructive advice so that they can continuously improve.

- Applying Finding to Teaching Improvements - Needs Development

  Presently there is no formal mechanism that uses the results of teaching evaluations to inform department plans. Certainly the results of the peer observations are shared with the faculty observed and can be used for individual self improvement. How the peer evaluations will be used in the future will be discussed once the initial round of observations is completed.

E.5 Planned Faculty Hires

This topic is also discussed in more detail in the Unit Goals section. Recent faculty hiring has largely followed the recommendations made by a 2017 advisory committee to the department head, consisting of seven faculty members who were elected by the physics faculty as a whole. Recommendations made by the previous APR were given due consideration (see Section C.2). The overarching recruitment target has been to increase the experimentalist to theorist ratio among the faculty, with the twin goals of increasing ICR return to the department and building a critical mass of experimentalists in a few subfields that would facilitate pursuit of larger grant opportunitites such as centers.

The recommendation of the hiring advisory committee was to target hires in the areas of experimental AMO physics, Condensed Matter physics (CM) physics, biophysics, particle physics, and cosmology. The advisory committee set a goal of eight hires in these areas over five years. Half of the hires would be in experimental AMO or CM physics. One faculty in each of these areas has been hired since the plan was adopted.

The committee strongly recommended building on the existing strengths within the department (and the university, when appropriate) and to avoid expanding in research directions that would be completely new. The advisory committee, however, also noted the departures and pending retirements of theoretical high-energy and nuclear physicists. Elsewhere (section C.2) we have also mentioned an additional hire through the TAP.

Because of the large start-up funds needed to hire experimental CM/AMO physicists, the hiring rate has been slower than optimal. Consequently, with retirements, the overall faculty size has remained flat in spite of seven new hires. An overview of the numbers of faculty who have been hired ("arrivals"), retired, resigned or deceased (summed as "departures"), and reviewed for promotion and tenure (including results) is given in Table 20.

Tables 21 and 22 list the department's hires and departures during the previous seven years.

Name	Departure Year	Reason
Ke-Chiang Hsieh	2011	Retired
William Wing	2011	Retired
Li-Zhi Fang	2012	Deceased
Philipe Jacquod	2014	Resigned (→ U West Switzerland)
Pierre Meystre	2016	Retired
Michael Shupe	2016	Retired
Bruce Barrett	2017	Retired

Table 22: Physics faculty departures

Name	Year	Promotion
LeRoy, Brian	2012	Associate
Stafford, Charles	2012	Full
Sandhu, Arvinder	2013	Associate
Varnes, Erich	2014	Full
Cronin, Alex	2015	Full
Su, Shufang	2015	Full
Fleming, Sean	2016	Full
Wolgemuth, Charles	2016	Full

Table 23: Faculty tenure decisions and promotions

In the last seven years, physics faculty achieved excellent results in tenure and promotion reviews. All recent cases submitted for review were successful (see Table 23). This success is a reflection of the stringent hiring criteria used by the department. Every new hire since at least 2005 has received prestigious awards and/or high recognition from their communities. For example, Table 9 shows the success of young faculty over the last seven years in terms of awards.

E.6 Compensation

Five physics departments were selected as our peers in Section D. These were the departments at Boston University, U.C. Davis, University of Florida, Indiana University and University of North Carolina. The compensation at UA and our peer departments for the academic year 2016-2017 for different faculty ranks is given in Table 24. The data for the peer institutions that are state universities were obtained from the UA's University Analytics and Institutional Research Office. The data for Boston University was not available.

University	Assistant	Associate	Full
Arizona	78,723	86,825	105,318
Peers	85,000	94,000	143,000

Table 24: Academic year compensation comparison with peer institutions

Compared to peer departments, faculty compensation for assistant, associate, and full professors is 93%, 92%, and 74% of the peer average. In fact, if one excludes department head, the average compensation for full professors drops to $102,127. In this case, the average compensation for full professors is only 71.5% of the peer department average.

In summary, the academic year compensation for assistant and associate professors is below average of peer physics departments while that for full professors is significantly below average. The low salaries for full professors result in salary compression that may limit the salaries for assistant and associate professors. As the UA aspires to be one of the top public universities in the US, the low full professor salaries along with the resulting compression may limit the ability of the physics department to compete with our peers in

Population	2011	2012	2013	2014	2015	2016	2017
Female	10.0%	10.0%	6.7%	6.5%	6.3%	9.4%	7.1%
Male	90.0%	90.0%	93.3%	93.5%	93.7%	90.6%	92.9%
Asian	23.3%	20.0%	16.7%	16.1%	15.6%	15.6%	17.9%
Hispanic/Latino	3.3%	3.3%	3.3%	6.5%	6.3%	6.3%	7.1%
Native American/Alaskan	3.3%	3.3%	3.3%	3.2%	3.1%	3.1%	3.6%
Non-Resident Alien	0%	0%	0%	3.2%	3.1%	6.3%	7.1%
White Caucasian	70.0	73.3%	76.7%	71.0%	71.9%	68.8%	64.3%

Table 25: Percentages of physics faculty by gender and race/ethnicity

attracting outstanding hires to the department.

E.7 Diversity

The gender and race/ethnicity composition of the faculty in the physics department is given in Table 25. The department is acutely aware of the need to increase the number of women and underrepresented minorities.

The AIP reports that in 2010, the fraction of women faculty at all ranks at departments that offered a Ph.D. degree in physics was 12% (http://www.aip.org/statistics/reports/women-among-physics-astronomy-faculty). The AIP also reports that in 2012, the fractions of hispanic and African-American faculty at departments that offered at least a bachelor's degree in physics were 3.2 and 2.1% respectively (http://www.aip.org/statistics/reports/african-americans-hispanics-among-physics-astronomy-faculty-0).

While the faculty composition in this regard is average or slightly below average, the department understands it must strive to do better. The short lists of most of the recent faculty hires have included at least one woman. However the pool from which women faculty are drawn (postdocs, national labs, other universities, industry) is small. Hiring of any new faculty is a very competitive and costly process. Especially for women and underrepresented minorities, the economic law of supply and demand applies and the department does not presently have any additional resources to bring to bear here. Nevertheless, the department is constantly searching for opportunity hires including candidates who are women. Elisabeth Krause, who was recently hired by the astronomy department and will be 0.25 FTE in physics, is one example.

E.8 Biographical Sketches

Short biographical sketches of the faculty are given in Appendix D.

F Unit Administration

The physics department organizational chart is shown in Figure 4.

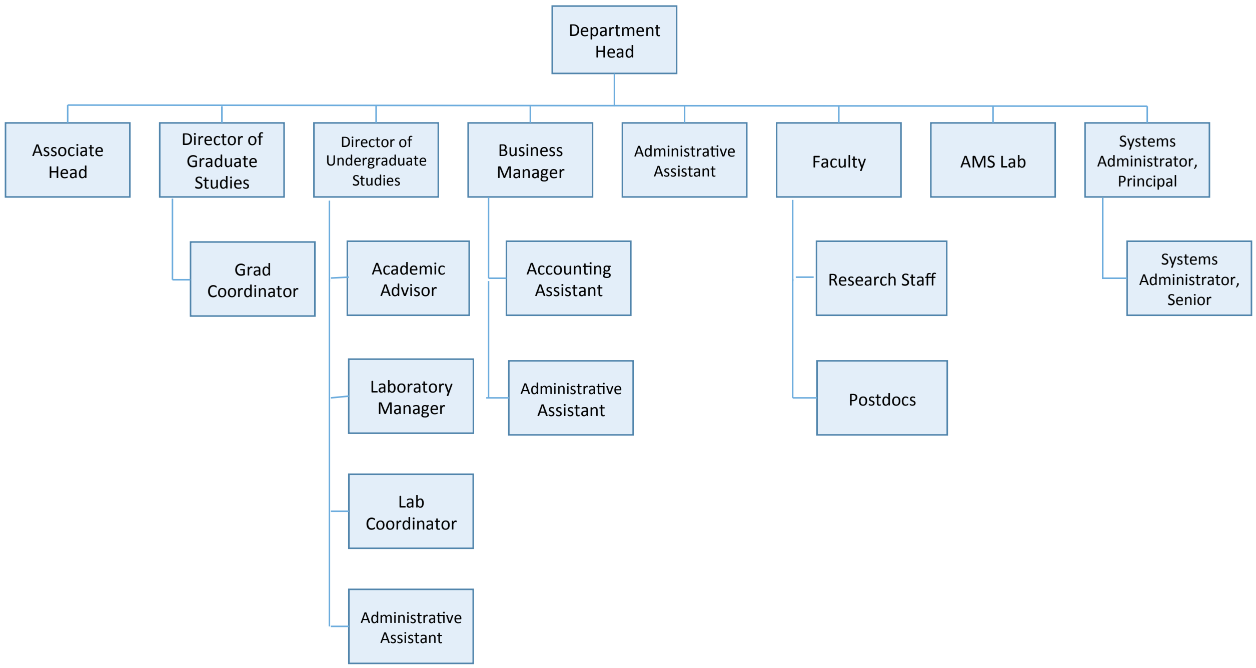

Figure 4: Physics department organization chart

The unit is led by the department head, Sumit Mazumdar. He is supported by an associate head, Ken Johns. The Director of Graduate Studies (DGS), Sean Fleming, oversees all issues related to the graduate program. Similarly, the Director of Undergraduate Studes (DUGS), Drew Milsom, oversees all issues related to the undergraduate program. The business office, which includes sponsored projects as well as the day-to-day finances of the department, is the responsibility of Shane Smith.

Departmental governance is handled by the organization described above as well as through a faculty governance structure. Faculty and staff committees are convened on an annual basis to develop programming and recommendations to the department head. A list of committees is given in Appendix E. Regular faculty meetings take place throughout the year (roughly one every six weeks) to discuss and vote upon modifications to academic programs, governance structure, and departmental policies. Additionally, there is a one day faculty retreat at the beginning of each academic year. The focus of the retreat is generally the two or three most important goals for the upcoming academic year. All members of the faculty, including the lecturers, are voting members of the faculty.

Table 26 lists the 11 classified staff in the department. (Holly Brown technically falls under appointed personnel). Although staff turnover since the last APR may appear to be relatively high, the main driver of these changes has been staff retirements. Of the seven staff members who have been with the department fewer than six years, five of those positions are replacements due to retirement. One position (Brown) is a newly created one. The department is aware of the importance of diversity. Four of the seven new hires were women and four of the seven were from ethnic minorities.

The largest decrease in staff support has been in the Academic Support Office (ASO). The reduction was a combination of retirements and decreased state funding. This office had a staff of three, but is now maintained by a single staff member. The reduction in academic support has meant that some functions are now supported by faculty members and that the staff is more reactive than proactive. For example, data analysis in support of the undergraduate or graduate programs can rarely be carried out.

For a few years the physics department business office was part of a College of Science (COS) business center,

Name	Position
Haiying Bai	Accountant, Associate
Holly Brown	Senior Academic Advisor I
Alexis Cibrian	Administrative Assistant
Michael Eklund	Systems Administrator, Senior
Larry Hoffman	Laboratory Coordinator
Matthew Jones	Systems Administrator, Senior
Hildegard Lueders	Program Coordinator
Carmen Montijo	Administrative Associate
Rohit Singh	Laboratory Manager
Shane Smith	Business Manager, Senior
Bonnie Wood	Accounting Assistant

Table 26: List of classified staff in the department

along with a few other COS departments. However, this arrangement proved to be unwieldy. Presently the physics department business office works solely to support the department. More information on the responsibilities of the ASO and business office can be found in Section G.

Efficiency is increased by training some staff members to carry out some duties normally outside of their responsibility. In this way, if a principal is sick or on vacation, some duties can be carried out by someone else. This applies to both the academic support office and business office.

G Unit Resources

G.1 Existing Unit Resources

Support services exist in the department for teaching, research, and administration. To a much lesser extent, support services exist for outreach. Presently all staff are state supported.

A number of departmental personnel support the teaching mission of the department. These include two senior instructors (Milsom and Jackson), a Laboratory Manager, a Laboratory Coordinator, an Academic Support Office (ASO), a Graduate Program Coordinator (GPC), and an Academic Advisor (AA). The two instructors significantly ease the teaching load of the department. Their teaching load is approximately three courses per semester. The teaching quality of the instructors is outstanding. The ability of both lecturers to teach nearly any undergraduate course as well as select graduate courses provides substantial flexibility in making faculty teaching assignments. Given the current size of the department, their significant course load permits specialty physics courses to be offered at both the undergraduate and graduate levels, as well as maintaining the course load for tenured and tenure-track faculty at one course per semester. A third instructor was recently hired and will start in fall 2018.

Both instructors are valuable resources for teaching in the department. One of the instructors (Milsom) provides assistance and guidance to faculty teaching core lower level courses. He (and collaborators) developed course materials to facilitate active learning in the lower level courses that are widely used by faculty teaching these courses. Both instructors also provide advice pertaining to course content and management. Milsom is also presently the Director of Undergraduate Studes (DUGS). Jackson recently developed an online version of the introductory algebra-based physics course (PHYS 102). A search for a third lecturer was completed and the new lecturer will start in fall 2018. The hire will help free faculty resources to expand the online course offerings from the physics department.

The ASO assists the DUGS and is an important resource for undergraduate students. The ASO helps students with all aspects of course registration and understanding degree requirements. Other responsibilities include scheduling rooms and times for lectures and labs, directing students to the appropriate advisor (academic or faculty), maintaining a list of tutoring resources, and placing textbook orders. The ASO supervises student workers who do photocopying of exams and other course materials. The ASO also helps plan department events such as the Blitzer award and the department graduation ceremony. Presently the ASO is staffed by 0.75 FTE, a reduction from the past made possible by online migration of many administration procedures.

The GPC assists the Director of Graduate Studies (DGS) and is an important resource for graduate students. The GPC helps graduate students navigate various administrative tasks associated with the graduate program. The GPC plays an important role in the graduate admissions process by organizing and checking student applications. The GPC also organizes the primary recruiting event, a Recruitment Weekend, for domestic students who have been offered admission. Record keeping is a yet another responsibility of the GPC. Presently the GPC is staffed by 0.75 FTE.

In 2016, with College of Science (COS) support, the department hired an AA. The AA plays many roles in the department, supporting not only the needs of 250 major and 30 minor students but also the needs of prospective and entering students. Directing the academic pathway of students is an important responsibility of this position. The AA also tracks student progress and provides pre-emptive measures to assist students who are struggling academically. Other responsibilities include coordinating summer and spring orientations for incoming students and holding several mandatory meetings with students throughout their career. The AA also participates in workshops covering such topics as getting involved in research, writing resumes, and searching for jobs. More information on the AA is included in Appendix F.

The responsibilities of the Laboratory Manager cover all aspects of running the undergraduate labs. The Laboratory Manager is responsible for making TA assignments to teach the lab (with help from the DUGS and GPC), training TA's each week to teach the labs and purchasing and maintaining equipment used in

Course	Description	Fee
PHYS 141	Introductory mechanics (calculus-based)	$50
PHYS 142	Optics and thermodynamics	$50
PHYS 161H	Introductory mechanics	$50
PHYS 162	Optics and thermodynamics	$50
PHYS 181	Introductory laboratory I	$50
PHYS 182	Introductory laboratory II	$50
PHYS 241	Introductory electricity and magnetism	$50
PHYS 261H	Introductory electricity and magnetism	$50
PHYS 381	Methods of experimental physics I	$150
PHYS 382	Methods of experimental physics II	$150
PHYS 405	Digital Electronics Techniques	$100
PHYS 481	Methods of experimental physics III	$150
PHYS 483	Methods of experimental physics IV	$150

Table 27: Courses with course fees

the labs. The Laboratory Coordinator assists the Laboratory Manager in the physical setup of labs each week. The Laboratory Coordinator is also responsible for purchasing, maintaining and setting up all physics demonstrations for the physics courses.

Equipment for student laboratories is funded through individual course fees. Table 27 gives the course fees currently charged for laboratory courses. The course fees are sufficient to maintain and upgrade equipment in the labs.

Funding for TA's is provided through a Temp Teaching fund from the COS. The number of TA's that can be supported is primarily determined by the number of labs needed for the introductory physics courses as well as the number of TA's used in active learning recitation sections. In general, the Temp Teaching fund is adequate to cover all lab teaching and grading needs each semester.

Two Systems Administrators are responsible for supporting the computing infrastructure of the department. Each of them are shared with another nearby department. One is 0.55 FTE and the other is 0.67 FTE in the physics department. The Systems Administrators are responsible for maintaining the undergraduate computing lab that provides 27 PC's running Windows 10 for use by undergraduates in their courses and the two computational physics courses (PHYS 105 and 305). Using Xming software, students can also use these machines to connect to a Linux server for scientific applications. The Systems Administrators also maintain 36 laptop computers and instructional computers that are used in the undergraduate physics laboratories. Staff and research activities are also supported by the System Administrators. In total they maintain over 425 devices (PC's, laptops, printers, ...) connected to the department computer network. They also maintain a number of digital displays in the building that advertise upcoming events and research in the department. One of the Systems Administrators also serves as the Building Manager for the Physics and Atmospheric Sciences building.

The department's business office supports administration and research activities in financial and personnel matters. The business office is responsible for establishing and maintaining accounting services for the department and research grants. It ensures University policy compliant and efficient operation of a broad spectrum of services, including payroll, human resources (hiring and benefits), purchasing, travel reimbursement, and financial reporting. The business office also educates department members in changes to University business policies and procedures. The Business Manager assists in research grant submission through Sponsored Project services at the University. The Business Manager also assists in research grant management through generation and monitoring of financial reports. The business office is managed by the Business Manager and is supported by Senior, Associate, and Assistant accountants. The Administrative Associate to the Head provides assistance for committee assignments including colloquium series, outreach, public relations, awards and prizes, and recruitment.

The department is fortunate to be supported by a small number of generous donors. Some of the donated funds are targeted, e.g. to support graduate student travel to conferences. Other gifts are unrestricted and support the teaching mission in various ways, e.g. to support the Undergraduate Research Symposium held at the end of each academic year. At the Symposium, undergraduates give 15 minute talks presenting their independent research to faculty members and other undergraduate students. The gift amount to the department is approximately $30,000 per year, with one donor generously giving a large fraction of this amount.

G.2 Resource Needs

As mentioned above, one specific need in regard to teaching resources was an additional lecturer, now satisfied. The GPC is in need of a reliable student assistant for 6-8 hours per week and also needs additional storage resources, such as file cabinets, etc. to maintain documents for the graduate program. In regard to IT resources, the Systems Administrators are presently both fractional FTE in the department. Some faculty feel that additional IT support, especially on the Linux side, would be beneficial to the research endeavors of the department. There is also a longstanding need for a permanent person to maintain and update the physics department website and help generate an effective newsletter. Finally, there is a need for additional common space for departmental use. Several small conference rooms do exist. However it is desirable to have a space for larger groups that could be used as a conference room for various teaching or research meetings.

H Undergraduate Program

H.1 Overview

The 2010 Classification of Instructional Programs (CIP) code for this program is 40.0801.

The physics department offers two undergraduate physics degrees: a B.S. and a B.A. The B.S. degree is the one most frequently awarded. This degree prepares students for a scientific career in industry, academia, or government. The B.S. degree program is the one recommended to students preparing for graduate school. The B.A. degree is intended for students wishing to apply a rigorous physics degree to other fields such as medicine, business or law. A Physics Minor is also offered for non-physics majors. The department plans to begin a B.S. in Applied Physics in fall 2019.

H.2 General Education

One Tier 2 General Education course is offered, PHYS 200 (The Science of Good Cooking). The course satisfies the Natural Science requirement. The syllabus for this course is given in Appendix G.

The learning outcomes and their assessment include

- Students will learn and apply the fundamentals of good scientific practice to cooking and preserving food. The writing assignments include keeping a lab notebook, designing experiments to test specific hypotheses, measuring and analyzing data, and reporting results in written form. The outcome is assessed by grading and written feedback on reports, as well as verbal comments in class on common mistakes and suggestions for improvement.
- Students will grasp the fundamental connections between the taste and texture of finished food and the structure and interactions of its constituent molecular groups. By extension, they will understand (and apply) how to manipulate the final properties of a dish by chemical means (e.g., thickening, brining etc.) The outcome is assessed by questions on midterm exams that include short answer, paragraph and essay forms. It is also assessed by judging appropriate experimental design in written reports.
- Students will grasp the nature of heat transfer by conduction and radiation and understand how to manipulate the taste and consistency of food by modifying the type of heat transfer and time of exposure. This outcome is assessed by semi-quantitative questions on midterms (e.g., graphing exercises, simple ratio problems etc.).

The writing requirements for this course are given in Table 28.

Course	Number of pages of writing required	Opportunity for revision provided after comments?
PHYS 200	12-18	No, but comments are given for each of six reports

Table 28: Writing requirements in PHYS 200

The opportunities for student learning for this course are given in Table 29.

Lecture/laboratory courses may be substituted for General Education Tier 1 and Tier 2 Natural Science requirements for students whose major is not science intensive. The following physics courses are approved for this requirement: PHYS 102/181, PHYS 103/182, PHYS 131/181, PHYS 132/182, PHYS 141, PHYS 142, PHYS 151, PHYS 152, PHYS 241, PHYS 242, PHYS 251, and PHYS 252.

Course	Think Critically	Communicate Effectively	Understand and Value Differences	Use Information Effectively
PHYS 200	Assessed Graded lab reports	Practiced Written reports	Not applicable	Introduced Student experiments

Table 29: Opportunities for student learning in PHYS 200

H.3 Undergraduate Programs

Enrollment data for undergraduate majors is given in Table 30. The majors count includes students who declare a double major with physics as primary or secondary. The B.S. in Engineering Physics was discontinued in June 2009 because of low productivity (enrollment). This degree was offered through the College of Engineering but administered by the physics department.

The average number of B.S. Physics majors is 206. The average academic level distribution as freshman, sophomore, junior, and senior students is 58, 47, 39, and 51. The department's experience is that the number of freshman majors is larger than this average. Uncertainties in the reported numbers may arise because some incoming freshman who intend to double major with physics only report a single major (e.g. astronomy or math). There has been a 10% increase in the number of majors in the last two years, however this is thought to be related to overall increased enrollment at UA.

	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
B.S. Physics majors	207	201	169	197	208	228	234
B.A. Physics majors	3	12	12	17	12	13	8
B.S. Eng. Physics majors	4	2	0	0	0	0	0

Table 30: Enrolled physics majors

Completed major data is given in Table 31. The average number of completed B.S. majors per year is 22. This number is a decrease of about 5 compared to the last APR report.

	2011	2012	2013	2014	2015	2016	2017
B.S. Physics majors	25	24	26	20	20	19	18
B.A. Physics majors	0	0	3	0	2	3	1
Eng. Physics majors	1	2	0	0	0	0	0

Table 31: Completed physics majors

According to American Institute of Physics (AIP) statistics, in numbers, the UA was tied for 49th in Bachelor's Degrees per year from Ph.D.-granting departments considering the classes from 2012 through 2014 (`http://www.aip.org/sites/default/files/statistics/undergrad/bachdegrees-p-14.pdf`). The department's proposal to offer a B.S. degree in Applied Physics (if approved) should help increase the number of completed majors.

In undergraduate teaching, the physics department has two main goals. The first is excellence in degree offerings for physics majors. The second is excellence in physics course offerings for non-majors, including engineering and life science majors.

In practice, almost all of the physics majors ($\sim$ 90%) pursue the B.S. track. Given the success of many of our students (including several who have gone on to top-ranked Ph.D. programs and academic careers) the faculty believe that our B.S. curriculum is largely succeeding in our goal of providing an excellent education for those students looking to continue to graduate school. At the same time the department is underserving those students who plan on non-academic careers after graduation. This is a sizable fraction (40-50%) of our majors. The applied physics degree is specifically designed to address this shortcoming and should increase both the number of majors and completed majors.

The department teaches large enrollment algebra-based and calculus-based introductory physics courses and labs to non-physics majors. In the last few years, nearly all of the lecture courses have been restructured to use evidence-based, active learning methodologies. This is described in more detail below.

There is no accrediting body that prescribes or reviews the curriculum.

The requirements for B.S. degree can be found in Appendix H. Web searches show that the B.S. curriculum offered by the department follows that of nearly all physics departments from Research I Universities. That curriculum includes four semesters of introductory physics (mechanics, electromagnetism, thermodynamics, wave and optics and modern physics), six upper division core classes (mechanics, electromagnetism, quantum mechanics and statistical mechanics) as well as courses in mathematical methods, computational physics, advanced laboratories, and special topics such as solid state physics, nuclear/particle physics and continuum mechanics. Additionally a final research project is required that can be fulfilled through PHYS 483 (advanced lab), PHYS 492 (directed research), or PHYS 498 (senior capstone). Students are also strongly encouraged to additionally participate in faculty research programs in many departments across campus.

The requirements for B.A. degree can be found in Appendix I. The B.A. degree is pursued by a small number of students who intend to work in fields outside physics such as law or medicine. The main difference between the degrees is the B.A. has a reduced number of required core courses and no research requirement.

As mentioned, the B.S. curriculum is very similar in scope to that found at most Research I Universities. While the introductory and intermediate level courses are primarily "classical", the faculty are aware of the need to include as many recent ideas and advances as are feasible. The more subfield-specific courses usually include recent developments in the the discipline through lectures or student presentations.

The curriculum for the proposed B.S. in Applied Physics is modified from the one for the B.S. degree. In this program, six three-credit courses are dropped from the B.S. degree and replaced with a course in communications, a course in data science or statistics, a two-semester collaborative engineering design project, and three three-credit technical electives. The two-semester engineering design project is run by the College of Engineering. It brings together several groups of four to six engineering and computer science students to collaborate on industry-sponsored projects. Physics students will be included in the future. A summary of the program is included as Appendix J.

In general course availability for majors is good. The principal advanced mechanics, electromagnetism, quantum mechanics, and statistical mechanics courses are offered each semester. The main challenges that exist are that elective courses are in some cases not offered as frequently as students would like due to the limited number of faculty. Elective courses are typically offered once every three to four semesters.

In 2013, UA was one of only eight universities to receive a three-year AAU grant to improve STEM undergraduate education at UA. The physics department participated in the grant proposal. One of several objectives was to transform one introductory class in each of five departments using evidence-based, active learning methodology, and the physics department was one. An initial (loosely) controlled experiment was carried out. One large section of PHYS 141, the introductory, calculus-based mechanics course was taught by an experienced faculty member who receives consistently high ratings from students. The other large section was taught by a postdoc in astronomy education with no teaching experience. The former would use the traditional lecture method while the latter would place heavy emphasis on using active learning during lecture and replacing one lecture per week with small student group activities. By the end of the course the section taught by the postdoc with no teaching experience had (very slightly) outperformed the section taught in the traditional way. At this point the department decided to teach PHYS 141 with one lecture per week substituted with small student group activities and with active learning also occurring during the two lecture periods (via voting cards, problem solving on small white boards, ...).

Currently, nearly all introductory physics courses, both algebra-based (PHYS 102 and 103) and calculus-based (PHYS 141 and 241) are taught using this methodology. All faculty who teach these courses agree to teach using an active learning approach. The final introductory course (PHYS 142) is in the process of also being transformed.

The use of active learning has begun to expand into other courses. PHYS 204 (Mathematical Techniques in Physics) now uses small group work regularly during lecture. The upper division PHYS 331 (Electricity and Magnetism I), PHYS 332 (Electricity and Magnetism II) and PHYS 371 (Quantum Mechanics I) also substitute small group problem solving sessions for some fraction of lectures. The Director of Undergraduate Studes (DUGS), Drew Milsom, organized several meetings for faculty to discuss how different active learning methods could be included in courses. About a third of the faculty have participated in Faculty Learning Communities (FLC) on campus where small groups of faculty meet twice monthly for a semester to learn how to implement effective teaching methodologies and subsequently practice them in at least one class.

Finally, the faculty in the department have the nearly universal opinion that a research experience is the most active learning strategy for physics. Working with a faculty member or group, the student will learn practical skills of the profession as well as to continue to develop critical analytical skills. Not infrequently the research experience reinforces material learned in the classroom.

As mentioned above, students are strongly encouraged to take advantage of the many research opportunities on campus in addition to the research required for the degree. Based on senior exit polls, approximately 75% of the students engage in research in the physics department or elsewhere on the UA campus. Each May the Department holds an Undergraduate Research Symposium where students can showcase their research. The Symposium includes a banquet lunch and an award for best research presentation. Faculty comments on the student presentations are used as part of program assessment.

Nearly 100% of the faculty use Desire2Learn (D2L) for some aspects of their course. The degree of use varies from instructor to instructor but in general D2L is used to post lecture notes, homework assignments and solutions, exam solutions, and grades. Faculty teaching the introductory physics courses often use voting cards and small white boards for student problem-solving practice. The white boards are used by a small minority of faculty in upper division courses as well.

Currently there are no online courses for required or elective courses. The department now offers an online version of the algebra-based PHYS 102 and is presently developing the associated laboratory course. Online courses for the calculus-based PHYS 141 are also planned for the future. The department closely follows the popularity and effectiveness of online courses in other departments in the College of Science (COS).

H.4 Undergraduate Students

The data on the quality of students selecting physics as a major, graduation rates, and time to degree compared with other fields are given in Appendix R. The following tables average these data over the last seven years (2010-2016).

In Table 32, the average SAT scores for incoming freshman physics majors, COS majors, and all UA students is shown. The data show that freshman students attracted to the department are of higher quality (based on SAT score) than those attracted to majors in the COS or all majors at the UA.

Physics Freshman Count	Ave. SAT	COS Freshman Count	Ave. SAT	UA Freshman Count	Ave. SAT
54	1241	1401	1137	7443	1105

Table 32: Seven year average of freshman counts and average SAT scores in physics, the COS, and the UA.

Table 33 shows the average fraction of Honors College students in the physics department, the COS, and throughout the UA. Students accepted into the Honors College are among the very best scholars at the University and must have at least a 3.5 GPA after taking 12 or more units. The large fraction of physics majors who are in the Honors program compared to majors in the COS and at the University of Arizona attest to the high quality of physics majors in the Department.

Physics Honors fraction	COS Honors fraction	UA Honors fraction
0.30	0.20	0.14

Table 33: Five year average (2012-2016) of the fraction of majors in the Honors program in the physics department, the COS, and the UA.

In Table 34 it is seen that the time to graduation for physics majors from 2011-2017 is the same for students in physics, all students in the COS and all students at the UA. This indicates the physics degree is not unreasonably difficult to obtain.

Physics Years to Degree	COS Years to Degree	UA Years to Degree
4.24	4.20	4.21

Table 34: Seven year average of the years to degree for students in physics, the COS, and the UA.

Table 35 shows the seven year average graduation GPA for physics majors as well as for all students in the COS and at the UA. The GPA for completed physics majors is similar to those for completed majors in the COS and the University of Arizona. This shows grades given by the physics department are similar to those in other departments at the UA.

Physics Completed Majors	GPA	COS Completed Majors	GPA	UA Completed Majors	GPA
23.0	3.30	1329	3.22	7078	3.19

Table 35: Seven year average GPA of completed physics majors, majors in the COS, and all majors at the UA.

The gender composition of the undergraduate majors is presented in Table 36. The fraction of women majors in the department is approximately 20%. AIP statistics on the representation of women in physics Bachelors programs was 20% in 2015. Thus UA has an average representation of women in the undergraduate program.

The Women in Physics (WiP) club was initiated in 2013. It goal is inclusion and is composed of both undergraduate and graduate students. WiP is strongly supported by the department administration. WiP provides women and others opportunities for professional discussion, outside speakers, and outreach activities.

The race/ethnicity composition is presented in Table 37.

Tucson Initiative for Minority Engagement in Science and Technology Program (TIMESTEP) is a group that meets biweekly on a variety of professional development topics such as impostor syndrome, implicit bias, and mental health. Additionally the group provides help on identifying and securing research opportunities, and applying to graduate school or industry. The meetings are expected to be especially effective in helping URM and first generation students prepare themselves for a successful career in STEM. TIMESTEP is organized by Gurtina Besla (PI, astronomy), Eduardo Rozo (physics), and our Academic Advisor (AA), Holly Brown. 100% of TIMESTEP attendees who completed an end of the year survey agreed with the statement that TIMESTEP is helping them reach their career goals. Further details about this program are available at (`http://lavinia.as.arizona.edu/~timestep/`).

The department strives to create a welcoming environment for all students. Though free space is very limited in the PAS building, an undergraduate lounge exists where majors can study or socialize. Additionally, there is a computer room with approximately 20 PC's running Windows for students to use. Using Xming software, students can also use these machines to connect to a Linux server for scientific applications. During most working hours, a graduate student is available in the "consultation room" where students, both majors and non-majors, can seek help with any physics course being offered. At least once a year the head, associate

	Gender	2010	2011	2012	2013	2014	2015	2016
B.S. Physics majors	F	44	33	29	38	36	43	54
	M	157	155	128	142	160	172	172
B.A. Physics majors	F	1	1	2	2	2	5	2
	M	2	11	10	15	10	8	6
Eng. Physics majors	F	2	1	0	0	0	0	0
	M	2	1	0	0	0	0	0

Table 36: Gender composition of undergraduate physics majors

	Race/ethnicity	2010	2011	2012	2013	2014	2015	2016
B.S. Physics majors	African American	6	7	3	6	8	7	7
	American Indian	4	3	4	6	10	9	8
	Asian American	11	12	9	9	10	12	12
	Hispanic	30	28	23	27	22	29	34
	Non-resident Alien	7	4	6	10	19	47	53
	Pacific Islander	0	0	3	2	2	2	1
	Unknown/Other	4	2	3	5	4	3	3
	White	139	136	106	114	122	106	108
B.A. Physics majors	African American	0	0	0	0	1	2	1
	American Indian	0	0	1	0	0	0	0
	Asian American	0	0	1	0	1	1	0
	Hispanic	1	2	2	7	5	3	0
	Non-resident Alien	1	1	1	2	1	1	2
	Pacific Islander	0	0	0	0	0	1	0
	Unknown/Other	0	1	0	0	0	0	1
	White	1	8	7	8	4	5	4
Eng. Physics majors	African American	0	0	0	0	0	0	0
	American Indian	0	0	0	0	0	0	0
	Asian American	0	0	0	0	0	0	0
	Hispanic	0	0	0	0	0	0	0
	Non-resident Alien	0	0	0	0	0	0	0
	Pacific Islander	0	0	0	0	0	0	0
	Unknown/Other	0	0	0	0	0	0	0
	White	4	2	0	0	0	0	0

Table 37: Race/ethnicity composition of undergraduate physics majors

head and Director of Graduate Studies (DGS) hold an open town hall meeting for the majors where any complaints or concerns can be raised. Each fall, the Directors of Undergraduate and Graduate studies hold a meeting for undergraduates to discuss the details of and answer questions about applying to graduate school. One of our emeritus faculty, J.D. Garcia, offers several meetings to help students prepare for the Physics GRE. However starting in 2018, the department will have to find a new leader for these sessions. All these substantial efforts send a message to our undergraduate majors that they are highly valued.

The honors courses offered are listed in Table 38. In some cases, the courses are co-convened with the non-honors course, but are augmented with additional learning opportunities (e.g. a final project). There are no specific efforts geared toward attracting or retaining honors students.

Course number	Course name
161H	Honors Introductory Mechanics
162H	Honors Introductory Thermodynamics and Optics
261H	Honors Introductory Electricity and Magnetism
263H	Honors Introductory Relativity and Quantum Mechanics
321∗	Theoretical Mechanics
331∗	Electricity and Magnetism I
332∗	Electricity and Magnetism II
371∗	Quantum Theory I
426∗	Quantum Theory II
472∗	Thermodynamics and Statistical Mechanics

Table 38: Honors courses offered in the physics department. Courses marked with ∗ are those that are co-convened with the non-honors version of the course.

The department's approach to academic advising changed substantially in 2016, when a dedicated AA Holly Brown was hired with support from the College of Science. The position is shared with the astronomy department. Brown has significantly improved the quality and quantity of academic advising of students. In many cases, the AA is the first point of contact for the students, and is able to resolve any issues they may have. The AA serves students their entire career at UA. The AA fulfills student needs from UA visits, at orientation, during the academic year and through graduation. The AA has mandatory advising meetings with every student each semester until the end of their sophomore year and a mandatory meeting to complete graduation paperwork. The AA provides approximately 15-20 hours of advising per week, both scheduled and walk-in. A summary of the AA responsibilities was previously given in Appendix F.

For questions that require a detailed understanding of the physics curriculum or involve career options, a group of three faculty members is also available to advise students. The faculty advisors in general have extensive experience teaching at the undergraduate level. The DUGS is one of the advisors. He serves as the "Lead Advisor" in the sense that he is extremely knowledgeable about University and department policies and rules as well as common problems that occur and their solution. He is an additional valuable resource for the faculty advisors. Each student is assigned to one of these faculty members.

All graduating seniors are asked to participate in an exit survey (Appendix L in which they can (among other things) respond about their immediate post-graduation plans and offer feedback on their educational experience. Participation is voluntary, with responses received from 101 out of 152 students who earned physics degrees from 2011 through 2017 (66% response rate). Of those who responded, 57 (56%) were planning to go to graduate school and had been accepted (most of these were in physics Ph.D. programs) with about 20% entering other fields), and 32 (32%) indicated that they were going on to non-academic positions. 0f these 32, 19 had secured positions at the time they completed the survey. The positions obtained were as technicians (6 students), in engineering (4 students), in computing (3 students), as high school teachers (3 students), and in the military (3 students).

In addition to the specific data collected above, we also ask the students to reflect on how well the physics degree program has prepared them for their chosen field. Among those who were planning to go on to graduate school, the responses were generally positive. On the other hand, the community of students headed for non-academic positions had more reservations about the quality of their preparation. Specific comments suggested that better technical preparation (in computing, for example) would have been beneficial, as well as access to advisors who were more familiar with non-academic career paths than physics faculty members tend to be. It is in response to these concerns that we are proposing the development of an applied physics degree path, which would be designed explicitly to meet the needs of students who would like to pursue non-academic careers.

H.5 Learning Outcomes Assessment

H.5.1 Expected Student Learning Outcomes

- Outcome 1 - Basic Physics Knowledge.

  Physics majors should have significant knowledge of the theories that form the basis of classical mechanics, electromagnetism, quantum mechanics, optics and thermodynamics.

- Outcome 2 - Critical Thinking.

  Physics majors will be able to design and conduct experiments in order to investigate physical phenomena. They will be able to document, analyze and critically interpret the results of these experiments.

- Outcome 3 - Skills for Physics.

  Physics majors will be able to use mathematical or computational skills in order to investigate physical phenomena. They will be able to document analyze and critically interpret the results of their work.

- Outcome 4 - Communication.

  Physics majors will be able to effectively communicate their results through written reports and oral presentations.

The assessment plan was developed by the assessment coordinator in consultation with the DUGS. The assessment plan was presented at the faculty retreat in 2017 for comment and approved. The assessment plan applies to both the B.S. and B.A. majors.

H.5.2 Assessment Activities

- Outcome 1 (Basic Physics Knowledge) is assessed using data from two courses, PHYS 331 (Electricity and Magnetism) and PHYS 371 (Quantum Mechanics). Outcome 1 is assessed using scores from the finals of these two courses, pre-exam and post-exam results of a standardized exam in PHYS 331 and post-exam results of a standardized exam in PHYS 371. The exams used are taken from the Physics Education Research literature. The electricity and magnetism exam comes from the University of Colorado. The quantum mechanics exam comes from the University of Pittsburg. We also use the results of an exit survey for graduating seniors given shown in Appendix L.

- Outcomes 2 (Critical Thinking) is assessed using the grades from the written report on the student creative research project in PHYS 382, an exit survey for graduating seniors and the results of a short survey filled out by faculty who attend the Undergraduate Research Symposium (Appendix M). The last third of PHYS 382 (Methods of Experimental Physics II) is devoted to a creative research project that is designed, carried out, and analyzed by the student (Appendix K). The student turns in a written report documenting the project and also gives an oral presentation to the class. The scores on the written report are used to help assess Outcome 2. The scores on the oral presentation are used to help assess Outcome 4.

- Outcome 3 (Skills for Physics) is assessed using an exit survey for graduating seniors and the results of a short survey filled out by faculty who attend the Undergraduate Research Symposium.

- Outcome 4 (Communication) is assessed using the grades from the oral presentation on the student creative research project (see above) in Phys 382, an exit survey for graduating seniors and the results of a short survey filled out by faculty who attend the Undergraduate Research Symposium.

H.5.3 Assessment Plan and Findings

A curriculum map is given in Appendix N.

- Outcome 1 (Basic Physics Knowledge)

  The success of this outcome is measured by good performance on final exam and standardized exams given in Phys 331 and 371. Student feedback via the exit survey for seniors is also used. The findings for Outcome 1 are pending the collection of another few semesters of data. One faculty member has written a reflective piece on what was learned from the results of the standardized exams. The senior exit survey data shown all students think the department does a relatively good job teaching core physics knowledge but a smaller fraction think the department does extremely well or very well in satisfying this outcome.

- Outcome 2 (Critical Thinking)

  The success of this outcome is measured by good performance in the research presentation made in Phys 382. It is also measured by student feedback via the exit survey for seniors. It is also measured by faculty opinions about the student research presented at the Undergraduate Research Symposium. In general, the performance metrics for this outcome are met.

- Outcome 3 (Skills for Physics)

  The success of this outcome is measured by student feedback via the exit survey for seniors. It is also measured by faculty opinions about the student research presented at the Undergraduate Research Symposium. In general, the performance metrics for this outcome are met. However there are also opportunities for improvement.

- Outcome 4 (Communication)

  The success of this outcome is measured by good performance in the research presentation made in Phys 382. It is additionally measured by student feedback via the exit survey for seniors. It is also measured by faculty opinions about the student research presented at the Undergraduate Research Symposium. In general, the performance metrics for this outcome are met. However there are also opportunities for improvement.

H.5.4 Changes Made in Response to Findings

The DUGS and Associate Head are made aware of all the findings. To date, no specific changes have been made in response to the findings. In part this is because the initial results on outcome assessment have been satisfactory. Going forward, the department will collect and analyze the detailed grading sheet associated with creative research project presentations in PHYS 382, rather than just the grade. This is to give a more detailed understanding of how this metric reflects on the desired outcomes. The test scores in PHYS 331 and PHYS 371 must be collected for a few more semesters until significant conclusions can be drawn. At least one instructor wrote a reflection piece on the PHYS 331 and PHYS 371 standardized exams results.

I Graduate Program

I.1 Overview

The 2010 Classification of Instructional Programs (CIP) code for this program is 40.0801.

There are two graduate degree programs offered by the physics department. The first is the Ph.D. program. The second is Professional Science Masters (PSM) program in medical physics. There is no official M.S. in the physics program, however the degree is often awarded to Ph.D. students who have passed the written comprehensive exam or as a terminal degree to students who have passed three of the four core subjects.

The requirements for a Ph.D. in Physics are given in Appendix O. The current coursework required for the Ph.D. student is 12 courses in physics (broadly defined) and three courses in the minor field (which is usually physics as well). The three courses in the minor field are required to be taken from three of eight subfields of physics, thus providing breadth to the degree. Students must pass a comprehensive written exam and an oral exam in order to advance to Ph.D. candidacy. In the oral exam, the student is expected to defend research that usually leads to their Ph.D. research as well as to answer general physics questions related to their research topic. Finally, a completed Ph.D. dissertation must be successfully defended by the student during an oral presentation (i.e. a thesis defense). Students successfully completing the Ph.D. program should be prepared to follow a career path towards achieving quality positions in academia or assuming leading technical roles in the private sector or government.

The PSM program in medical physics was established in 2007. It grew out of earlier PSM program in Applied and Industrial Physics. The PSM in medical physics is a joint program between the departments of physics and radiation oncology.

Significantly, the PSM program gained Commission on Accreditation of Medical Physics Education Programs (CAMPEP) accreditation in 2012. CAMPEP ensures that the program provides a rigorous and thorough education for students enroute to a career in medical physics. Students who successfully complete this degree should be well prepared for the Part 1 Examination in Radiologic Physics administered by the American Board of Radiology and will be ready to enter a medical physics residency program.

The PSM requirements are given in Appendix P and students must take 36 or more units of courses selected from physics, radiation oncology, optical science, and biomedical engineering. Courses in human anatomy and physiology are also suggested. A summer internship in medical physics is an additional requirement.

Specialty graduate programs in biological physics and theoretical astrophysics exist. Both provide faculty support and research opportunities that cut across normal departmental boundaries. The course requirements for students pursuing a Ph.D. in these programs are the same as for other Ph.D. students.

In 2009, a chemical physics program was added as a new specialty program. This is an interdisciplinary track that enables students to pursue cutting edge research at the boundaries of physics and chemistry. Students in the program have worked in diverse fields such as nanoscience, biological physics, and astrochemistry. The program recognizes the high impact such an interdisciplinary and collaborative program can bring to solving modern research problems. This flexible program allows students to take core courses from both the physics and chemistry departments. Several faculty from the chemistry and biochemistry department hold courtesy joint appointments in physics. A few students have been involved in crossover Ph.D. dissertation research under the supervision of faculty from the partner department.

I.2 Curriculum and Courses

Table 39 shows the number of Ph.D. students per year, the number of first year Ph.D. students per year and the number of PSM medical physics students per year.

	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
Enrolled Ph.D. students	74	73	71	71	72	75	87
First year Ph.D. students	13	16	14	11	17	10	22
Enrolled PSM students	0	0	3	9	7	6	4

Table 39: Enrolled and first year Ph.D. students and PSM students

	2011	2012	2013	2014	2015	2016	2017
Completed Ph.D.'s	7	12	11	8	8	8	12
Completed PSM	0	0	1	4	3	4	4

Table 40: Completed Ph.D. and PSM degrees

The number of completed Ph.D's is shown in Table 40. The median time to Ph.D. degree for degree completions between 2011 and 2017 is 6.5 years. The number of Ph.D's awarded during this period was 66. The median time aligns with national averages. Data from NSF on science and engineering doctorates finds the median time to Ph.D. in physical sciences and earth sciences was 6.6 and 6.1 years in 2011 and 2016 respectively (http://www.nsf.gov/statistics/2018/nsf18304/datatables/tab31.htm). Data from the APS give the average length of time to earn a Ph.D. in physics in the combined classes of 2010 and 2011 was 6.3 years (http://www.aps.org/careers/statistics/upload/trends-phd0214.pdf).

The Ph.D. completion rate is based on the average of five entering cohorts. The six and eight year completion rates are given in Table 41 for three sets of five year periods The previous APR report gave the six year completion rates for all physics students who graduated in academic years 2003-2005 as 25%. The completion rate for males and females was nearly identical during that period. The six year completion rates are taken from the publication *A Data-based Assessment of Research Doctorate Program in the United States* (https://grants.nih.gov/training/research_doctorates.pdf) published in 2011. The completion rate for physical and mathematical sciences was 43% using data collected in 2005-2006.

Completion Rates (%)	M	F	Total
Six year (2006-2010)	30.2	50.0	31.9
Eight year (2006-2010)	64.4	75.0	65.3
Six year (2007-2011)	31.8	25.0	31.2
Eight year (2007-2011)	57.8	50.0	57.1
Six year (2008-2012)	31.9	12.5	29.1
Eight year (2008-2012)	55.3	37.5	52.7

Table 41: Six and eight year Ph.D. completion rates for three five-year cohorts

There were several changes implemented since the last APR designed to improve the completion rate and time to Ph.D. These include changes to the written comprehensive and oral comprehensive exams described below. Also, each student is required to meet with their dissertation committee once per academic year to report on research progress towards a thesis and any problems encountered.

The format to pass the written comprehensive exam was changed in 2016. Previously students had twice yearly attempts to pass an exam that contained problems from all the four core areas: quantum mechanics, classical mechanics, electromagnetism, and statistical mechanics. More weight was assigned to the quantum mechanics problems. Students had to pass this exam by the end of their third year, though in some cases they could petition for a final attempt in their fourth year. Currently, students must pass four separate exams, each containing problems from one of the core areas. Once they pass an exam for one core area they do not need to retake the exam in that area. Students must pass exams from the four core areas by the end of their academic year.

The change to the written comprehensive exam was made after consultation with the graduate students. Almost all were in favor of some sort of written physics test on core material. However, the old exam format was a very high stress event for the students, in part because the core material is tested all at once. The subject by subject exam format was proposed to reduce the stress and improve the exam outcomes. The new format for the written comprehensive exam was proposed and discussed at a faculty meeting. It was adopted by the faculty in the form above.

The format for the oral comprehensive exam was also changed. It now requires an oral defense of a proposed Ph.D. or related project in addition to answering general physics questions related to this research topic. In order to successfully pass the oral exam, the student must necessarily become actively involved in research relatively early. This requirement helps shorten the time to degree since some research topic needs to be identified by the end of the third year of study.

Graduate courses are divided into two categories: core and electives. Since none of the courses are actually required the designation of elective is somewhat misleading. Most students however take 1-2 courses in each of the core physics areas listed above. These courses provide a foundation upon which more specialized knowledge is based. They also cover the subject matter that is tested by the written comprehensive exam. These courses are offered every year.

Graduate electives constitute courses with more specialized content that focus on a given subfield in physics such as condensed matter, Atomic, Molecular, and Optical physics (AMO), particle physics, etc. while some electives are offered every year, others are offered less frequently, typically once every eighteen months to two years. The elective courses prepare students to conduct research with the faculty. The course subfields correspond approximately to the subfields represented by the faculty. In addition, the graduate students are polled via email for input into which courses they want to see offered in the upcoming academic year.

In general, faculty do not use/emphasize active learning techniques in graduate courses. Students are strongly encouraged to take two semesters of PHYS 599, which is independent study under the direction of a faculty member. The idea of this course is that students can experience and become immersed in the day-to-day research environment of a faculty member or group in a physics subfield in which the students are interested. The specific independent study activities vary from professor to professor or group to group but most involve active learning experiences such as laboratory work, computer simulation, or mathematical calculation.

Nearly all first and second year graduate students are appointed as teaching assistants (TA's) for the introductory physics courses. All students are required to attend a series of mandatory training sessions the week before classes begin. They are also required to attend a weekly training session on the upcoming lab they will be teaching. First year TA's for labs are observed for the entire lab period by faculty member. The observations are not announced. Students are given feedback on their performance within 24 hours and the Director of Undergraduate Studes (DUGS) is also informed of the results. Some TA's participate in the active learning activities used in the introductory courses, either in the recitation sessions or during lecture.

Most of the faculty use the Desire2Learn (D2L) course management system to post homework assignments and homework and exam solutions. A smaller number use D2L to post lecture notes or supplementary course material.

No online courses are available for core or elective courses. There are no plans presently to develop any online graduate courses.

There is adequate but tight space for graduate students to carry out their studies. Cubicle space for TA's is provided in several rooms throughout the PAS building. Unoccupied office space is a minimal in the department. The department has made some effort to improve the condition of the cubicle space (cleaning, whiteboards, ...). RA (Research Assistant) graduate students typically have shared offices in space provided by their research advisor or group.

Graduate students have adequate computing and supplies to carry out their studies. A large fraction of graduate students have personal laptops. Most RA's have access to additional computing within their research group. Students also have access to the UA's supercomputer. Some groups make heavy use of DOE supercomputers. Resources such as printers or copiers are readily available to the graduate students. The undergraduate computer lab is also available to graduate students who need access to Windows machines.

A small fraction of graduate students (< 10%) take a minor outside of physics. An even smaller fraction of students outside physics use physics as a minor. There are no known coordination problems.

The handbook for graduate physics students can be found here (http://w3.physics.arizona.edu/sites/default/files/grad/grads_handbook.pdf).

I.3 Graduate Students

The physics department uses several different means to recruit graduate students. The foundation for recruitment must come from the high quality, cutting edge, and visible research programs pursued by the faculty. A physics department web site is maintained and frequently updated with national and local news items related to faculty research and awards. Most prospective students use the website to gather information.

Additionally, faculty indirectly recruit through their colloquia and seminars at universities as well as through research ties with other universities. Finally, up-to-date brochures describing the graduate program and areas of research excellence are sent to targeted undergraduate schools around the country.

A very effective recruiting weekend is held for all domestic students who are admitted to the graduate program. Airfare and lodging expenses are paid by the department. Students intensively interact both professionally and socially with faculty and graduate students. Short talks describing departmental research are given to the students along with lab tours. Additionally, the Director of Graduate Studies (DGS) and senior graduate students give talks on academic expectations as well as practical matters of being a UA physics graduate student. There are also several social events for all faculty and graduate students during the weekend. The recruiting weekend is successful in the sense that a large fraction (approximately 50%) of those students who visit the department during that weekend ultimately matriculate to Arizona.

The graduate program receives approximately 130-140 applications for spots in our Ph.D. program. This is more than the typically 40-60 offers that are made. Approximately 25-30% of the offers are subsequently accepted. While the program is successful at recruiting good students it is far harder to convince the very top students to consider our program. The main draw these students have to come to UA is to work with a particular faculty member. Thus the ability to recruit the best students is directly related to the quality of the research program in the physics department. For those students that are interested in working with a particular faculty member or an area of research which is represented at UA the faculty and/or group contacts the student directly.

The data on women in the graduate Ph.D. physics program are given in Table 42.

	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
Number	11	14	12	11	13	13	15
Percent	14.8	19.2	16.9	15.5	18.1	17.3	17.2

Table 42: Women in the graduate Ph.D. program

The data show that on average 17.0% of the enrolled Ph.D. students are women.

Assuming that all these students continue to earn their Ph.D. in physics, then this average fraction is slightly below the national average in 2015. The national average data on the percent of physics Ph.D.'s earned by women is taken from http://www.aip.org/statistics/physics-trends/representation-women-among-physics-bachelors-and-phds). The fraction of women earning Ph.D.'s continues to trend upwards, with a 20% fraction being awarded in 2015.

The physics department is acutely aware of the proportionally small fraction of women graduate students. The department acknowledges that physics is one of the last areas in the sciences where there is significant under-representation of women and minorities relative to their proportion of the population. We understand that the loss of the participation of women in physics occurs increasingly at the undergraduate, graduate, and faculty levels.

The department's awareness of the low fraction of Ph.D. students who are women extends to the Admissions and Recruitment Committee. Great care is taken to ensure that all qualified women are admitted by taking a broad look at their applications. Additionally, during the recruitment weekend described above, efforts are made to make the women applicants feel as welcomed as possible. A lunch for prospective students during the recruiting weekend is hosted by the Women in Physics (WiP) club, for example. Small supplements ($4000 per semester) for women and underrepresented minorities through the Graduate Access Fellowship are pursued when possible.

The data on under-represented minorities (URM)'s and other ethnic groups in the graduate physics program is given in Table 43. The fraction of URM's is obviously very low and similar to that found in most Physics Departments across the country. In the period 2013-2015, only 65 physics Ph.D.'s were awarded to (US) URM's each year, which is about 7% of the total physics Ph.D.'s awarded (www.aps.org/programs/education/statistics/minoritydegrees.cfm).

While the fraction of URM's enrolled in the Ph.D. program is decreasing, we do not consider this a trend given the small absolute number. On the other hand, the small absolute number is a concern and the Physics Department is taking steps in order to increase the enrollment and degree completion of URM Physics Ph.D.'s.

	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
Hispanic	1	1	1	3	4	4	4
Percent	1.4	1.4	1.4	4.2	5.6	5.3	4.6
Asian American	1	0	0	2	3	2	2
Percent	1.4	0.0	0.0	2.8	4.2	2.7	2.2
Non-resident alien	31	33	32	31	29	33	38
Percent	41.9	45.2	45.1	43.7	40.3	44.0	43.7

Table 43: Ethnic composition of the graduate Ph.D. program

The fraction of Hispanic students was approximately flat during the last seven year period. The department took several initiatives to increase Hispanic enrollment but they have not been fruitful. The UA physics department partnered with the University of Texas at El Paso (UTEP) physics department for a period of time. The UTEP physics department had a fifth year Master's degree program in which the UTEP seniors would take graduate core courses and participate in research. It was jointly decided with UTEP that the UA comprehensive exam would be offered for UTEP students to take. Up to 50% of the exam questions could be substituted by UTEP physics faculty. If the student passed the exam, they would be admitted into the UA Ph.D. program with course and comprehensive exam credit. However no students followed this path. With the move of the UTEP department head (Vivian Incera), our primary contact at UTEP, to another institution, this effort has come to a halt.

Related to this bridge program, UA and UTEP exchanged colloquium speakers for a couple years during 2010-2016. Also, each year the UA physics department supported one or two Summer Research Institute (SRI) students, primarily from UTEP, but also from New Mexico State University, Las Cruces. The SRI program is run by the UA Graduate College. It targets especially URM's and it an extensive summer program that not only provides a stipend for students to do research with UA faculty but also prepares the students for graduate studies at UA and elsewhere through coursework and workshops. The physics department supported one or two students each year, except in 2017.

The fraction of foreign students in the graduate program has remained more or less constant at 45% during the period covered by the APR.

All admitted Ph.D. graduate students are guaranteed financial support, including health insurance. In general, all Ph.D. students are compensated as TA's or RA's. The compensation for students is dependent on whether or not they have passed the comprehensive written and oral exams. The "pre-comprehensive" compensation is approximately 18,400$ and the "post-comprehensive" compensation is approximately 19,000$.

These are academic year salaries. Both RA's and TA's are typically hired at 0.5 FTE, which amounts to 20 hours/week. Students may earn an additional 4/9 times their academic year compensation by working as 1.0 FTE RA's for two months during the summer. All Ph.D. student RA's and TA's hired at the 0.5 FTE level have their out-of-state tuition waived. In addition, 100% of registration fees are remitted. The miscellaneous student fees that the student is responsible for are approximately $663.00/semester. Health insurance is covered as a benefit of their assistantship and they receive a 10% discount at the Bookstore. The low cost of living in Tucson makes the graduate student stipend a livable one.

As concerns travel money for conferences and workshops, travel for many RA's is supported through the research grants of their advisors. Additionally, travel grants for students attending or presenting research at academic or professional conferences is available through the Graduate and Professional Student Council (GPSC). Within the department, the C.Y. Fan "FanFare" Award is a memoriam award that provides partial support for travel to conferences for four-eight graduate students per year. Also, travel to the APS Four Corners Meeting (regional APS meeting) is subsidized by the department.

The number of faculty is 28. The number of Ph.D. students is in 2017 was 91. Of these students a total of 38 passed both comprehensive exams and 9 have advisors in another department. Thus the ratio of Ph.D. students who have passed both comprehensive exams to faculty is 1.6. This number seems reasonable. Taking into account that not all faculty are 1.0 FTE and not all are research active, most faculty are working with 1-2 graduate students on research projects. This number would be typical in other peer physics departments.

A subset of graduate student placements is given in Tables 44 and 45.

Name	Ph.D. date	Placement
Ziran Wu	2010	Postdoc at U. Toronto
Menika Sharma	2010	Postdoc at IISc, Bangalore, India
Justin Bergfeld	2010	Postdoc at UC Irvine
Xinyu Miao	2010	Financial district
Arif Emre Erkoca	2010	Business director at Electronics Valley
Vincent Lonij	2011	Quantitative Analyst at Bloomberg New Energy in London
Xiaowen Lei	2011	Postdoc at UA physics dept.
Emanuele Mereghetti	2011	Postdoc at LANL
Hongtao Li	2011	Business Ph.D. at U. Rochester
Joseph Baker	2011	Postdoc at U. Chicago
Lance Labun	2011	Postdoc in Taipei, Taiwan
Walter Freeman	2011	Postdoc at George Washington Univ.
Michael Fickinger	2012	Software Consultant at TNG Technology Consulting
Michael Kruse	2012	Postdoc at LLNL, Berkeley
Regina Azevedo	2012	Lecturer at the Centro Federal de Educação de Minas Gerais and at the Centro Universitário do Planalto de Araxá, Araxá, Brazil.
Jiamin Xue	2012	Postdoc at UT Austin
Adam Roberts	2012	Scientist at Northrop Grummann, Los Angeles
Caleb Parnell-Lampen	2013	Engineer at the Aerospace Corp.
William Holmgren	2013	DOE Sunshot Fellow postdoc at the UA atmospheric sciences dept.
Niranjan Hirisave Shivaram	2013	Postdoc at LBL, Berkeley
Jonathan Meair	2013	Instructional faculty at Pima Community College
Joshua Barr	2013	Software engineer
Lei Xu	2013	Western Digital Corp.

Table 44: Job placements of Ph.D. students - 2010-2013

Name	Ph.D. date	Placement
Shulei Zhang	2014	Argonne National Lab
Ivan Hromada	2014	Optics Engineer at NP Photonics, Tucson
Henry Timmers	2014	NRC Associate at NIST, Boulder
Jonathan Eckel	2015	Data analyst
Daniel Cormode	2015	Engineer at SOLON corporation
Otar Sepper	2015	Software engineer at Wall Street
Jason Veatch	2015	Postdoc at U. Gottingen
Fionnbarr O'Grady	2015	Med. Phys. student at Penn
Matthew Yankowitz	2015	Postdoc at Columbia Univ.
Felix Kling	2016	Postdoc at UC Irvine
Huanian Zhang	2016	Postdoc at UA astronomy dept.
Yijun Ding	2016	Univ. of Co. Hospital postdoc
Maxwell Gregoire	2016	NRC postdoc at the Air Force Research Lab in Albuquerque
Robert Leone	2016	Analyst at the Mitre Corp.
Ou Zhang	2016	Visiting scientist at UT Austin
Alexander Brummer	2017	Postdoc at UCLA
Adarsh Pyarelal	2017	Postdoc at UA computer science dept.
Jeffrey Kost	2017	Postdoc at IBS in KAIST, Daejeon, Korea
Hamid Almasi	2017	Postdoc at Northwestern Univ.
Niladri Gomes	2017	Sr. System Design engineer at GlobalFoundaries, Albany
Sarah Jones	2017	Research staff at IDA (Washington, D.C.)
Dheeraj Golla	2017	Systems engineer at Cymer Inc., San Diego
Tony Lorenzo	2017	Postdoc at the UA atmospheric sciences dept.
Chen-Ting Liao	2017	Postdoc at UC, Boulder

Table 45: Job placements of Ph.D. students - 2014-2017

I.4 Learning Outcomes Assessment

I.4.1 Expected Student Learning Outcomes

- Outcome 1 - Physics Knowledge. Physics Ph.D.'s will have a deep knowledge of the theories that form the basis of classical mechanics, electromagnetism, quantum mechanics and statistical mechanics
- Outcome 2 - Experimental Skills. Physics Ph.D.'s in experimental subfields will be able to design and conduct original experiments in order to investigate physical phenomena. They will be able to analyze data and publish these results in scientific journals
- Outcome 3 - Theoretical Skills. Physics Ph.D's in theoretical subfields will be able to construct original theories in order to explain or predict physical phenomena. They will be able to describe and publish their work in scientific journals.
- Outcome 4 - Communication. Physics PH.D.'s will be able to effectively communicate their results through written reports and oral presentations.

The assessment plan was developed by the Assessment Coordinator in consultation with the DGS. It was presented at the faculty retreat in 2017 for comment and approved.

I.4.2 Assessment Activities

- Outcome 1 (Physics Knowledge) Outcome 1 is assessed via the results of the written comprehensive exam. Students generally take core courses in classical mechanics, electromagnetism, quantum mechanics and statistical mechanics during their first two years of the graduate program. Four exams, one in each of the core physics areas, are offered twice per academic year. There are four problems on each exam and the exam is constructed by a faculty exam committee. Students must pass all four exams within three years of entering graduate school. Once the students pass an exam in a core area they do not have to retake that particular exam. Each problem is graded by two faculty members and their scores must be in relatively close agreement. The pass line for each exam is suggested by the exam committee after analyzing the results. The pass line is then possibly modified at a full faculty meeting, but typically is set at 50%. The faculty have agreed that passing the written exam satisfies the requirement that students have a deep knowledge of these four core physics areas.

- Outcomes 2 (Experimental Skills) and 3 (Theoretical Skills) Outcomes 2 and 3 are meant to apply to students in experimental physics and theoretical physics respectively. These outcomes are assessed by the successful completion of thesis research, a written dissertation, and thesis defense. The thesis research, original research in a subfield of physics, is carried out over several years under the direction of a faculty thesis advisor. The dissertation is written during the last several months of research. The dissertation and defense presentation is closely examined by a thesis committee of five members. In some cases, the thesis committee may suggest revisions to the dissertation. The thesis committee is given a short presentation each academic year reporting progress and any problems encountered in the research. In most cases, one or more publications in a referreed physics journal results from the student's research. The faculty have agreed that passing the thesis defense satisfies the requirements of Outcomes 2 or 3.
- Outcome 4 (Communication) Outcome 4 is also assessed during the thesis research. Most students will orally present the results of their research at national or international physics conferences. During their research they also likely produce written documentation of their research methods and results. The dissertation is of course one such written document. The thesis defense is of course one such oral presentation.

I.4.3 Assessment Plan and Findings

A curriculum map is given in Appendix Q

- Outcome 1 (Physics Knowledge) The success of this outcome is measured by the fraction of entering cohort passing the written comprehensive exam and the pass fraction of the four written comprehensive exams. The new format for the written comprehensive exams begin in 2016. Though the new format appears to be well-received by the students, a more formal survey will be taken in fall 2018. Student performance on the exam is generally good, with a possible exception of the electricity and magnetism exam.
- Outcome 2 (Experimental Skills) The success of this outcome is measured by the number of successful Ph.D. completions, the fraction of students in a given cohort who have passed their comprehensive exams that subsequently completed their Ph.D., and a survey given to the thesis committee and thesis student. The number of Ph.D. completions is satisfactory. The survey has not yet been implemented.
- Outcome 3 (Theoretical Skills) The success of this outcome is measured by the number of successful Ph.D. completions, the fraction of students in a given cohort who have passed their comprehensive exams that subsequently completed their Ph.D., and a survey given to the thesis committee and thesis student. The number of Ph.D. completions is satisfactory. The survey has not yet been implemented.
- Outcome 4 (Communication) The success of this outcome is measured by the number of successful Ph.D. completions and a survey given to the thesis committee and thesis student. The survey has not yet been implemented.

I.4.4 Changes Made in Response to Findings

The most important outcome early in a graduate student's career is Outcome 1. Based on the results of the written comprehensive exam, the DGS will confer with individual students and develop a plan of study for the student. Most of actions in response to the findings take place at the individual student level since all circumstances are different. A specialized plan of study for the student is made in consultation with the student and perhaps a research advisor.

Given that the format of the written comprehensive exam changed recently (2016), the faculty are monitoring the results to gauge if any further changes are warranted. The faculty and graduate students are satisfied with the research-oriented oral comprehensive exam.

The DGS and associate head will develop a short survey to be taken by the Ph.D. student and his/her Ph.D. defense committee short after the Ph.D. defense. The survey must be constructed carefully to avoid it from becoming a trivial exercise. Ideally the survey will be implemented in Qualtrics to avoid paper copies and transcription. However lack of faculty and student compliance is a concern with the online survey.

I.5 Post-Doctoral Fellows

All postdoc-doctoral fellows (postdocs) are hired by individual faculty or research groups. Postdocs are mentored by the individual faculty or research groups. Some faculty grants (e.g. those from NSF) require a mentoring program for postdocs. The department has essentially no involvement in this process. Postdocs contribute exclusively to the research mission of the department.

The number of postdocs in the department is approximately 8 per year. The range of time a postdoc stays with a research group can range from one to five years but a typical appointment is three years. Positions taken by recent postdocs are given in Table 46.

Name	Year	Research Area	Position
Rikard Enberg	2010	Particle Theory	Faculty at Uppsala University
Brooks Thomas	2010	Particle Theory	Postdoc at U. Hawaii
Jimmy Rotureau	2011	Nuclear Theory	Postdoc at Chalmers University, Sweden
Lance Labun	2012	Nuclear Theory	Postdoc in Taipei
Vincent Lonij	2012	Solar Energy	Bloomberg New Energy
Vikram Rentala	2012	Particle Theory	Postdoc at Michigan State
Chieh-Jen Yang	2013	Nuclear Theory	Postdoc at University of Trento
Venkat Kaushik	2013	Particle Experiment	Unitrends, Inc
Jongjeong Kim	2013	Particle Theory	Seoul National University
Ludmilla Levkova	2013	Particle Theory	University of Utah
Barath Coleppa	2014	Particle Theory	Faculty at Indian Institutes of Technology
Will Holmgren	2014	Solar Energy	DOE SunShot Postdoc
Karan Aryanpour	2015	Condensed Matter Theory	Senior Engineer, Raytheon
Atri Bhattacharya	2015	Particle Experiment	Postdoc at University of Leige, Belgium
Jeremiah Birrell	2015	Nuclear Theory	Asst. Prof. in UA Applied Math
Alex Abate	2016	Particle Experiment	Dia and Co.
Tirthankar Dutta	2016	Condensed Matter Theory	Beijing Computation Science Research Center
Xiaowen Lei	2016	Particle Experiment	Expedia, Inc
Thom Primer	2016	Particle Theory	
Ruchika Nayyar	2017	Particle Experiment	Vervega Analytics
Srimoyee Sen	2017	Nuclear Theory	Postdoc at Inst. for Nuclear Theory, Seattle
Venkatesh Veeraraghava	2017	Particle Experiment	Returned to India
David Yayali	2017	Particle Theory	Aeronautical Engineering at glsua
Yu Seon Jeong	2018	Particle Theory	CERN Fellow
Youngsoo Park	2018	Cosmology	KIPMU, Stanford
Luka Leskovec	2018	Particle Theory	Jefferson Lab
Peter Zimmerman	2018	General Relativity Theory	Postdoc at MPI for Gravitational Physics

Table 46: Positions taken by postdocs immediately after UA

J Academic Outreach

The department engages in several forms of outreach to the local community, with the goals of educating the public about the work faculty do and its importance, recruiting local high school students to consider becoming physics majors, and soliciting donations to the department and the College of Science (COS). This is an area where the department has substantially increased our efforts since the previous APR.

In Fall 2010 the department, led by faculty Manne, initiated the Physics Discovery program for outreach to visiting school groups. This program trains teams of physics undergraduates and grad students to lead guided demonstrations to K-12 school groups. The department secured a permanent outreach space in the Flandrau science center, which handles the scheduling and coordination with other campus STEM outreach. Over the past 7 years, the program enrolled approximately 30 undergrads and 15 grad students to perform outreach to an estimated 4000 schoolchildren, with the most common age range being 9-11 years old. The spring 2018 program is already completely booked with about 350 visiting schoolchildren. The Physics Discovery experience lasts for 1-2 hours, during which the visiting students rotate in small groups through stations where mechanics, electricity and magnetism, thermal physics, and optics are explored. To support this program, a new course was developed to train our students in outreach techniques. Enrolled students meet for an all-day instructional workshop at the beginning of the semester, where they receive training in the science content as well as on instruction and crowd-control techniques appropriate for different age levels. The value of entertainment as a vehicle for instruction is stressed. All outreach students are required to communicate the unifying theme and take-home lesson from each station. Several of our undergraduates who went through the program reported that their outreach experiences were made a strong selling point in their graduate school applications.

Another recent initiative is the creation in 2012 of an annual "Physics Open Day" where the public is invited to our department to hear a public lecture as well as to tour laboratories and hear presentations from some of the research groups. This event is held on a Saturday, in conjunction with the Tucson Festival of Books event on campus, and has proven to be quite successful, with about 100 people or more typically attending. The Open Day operates in conjunction with the "Science City" outreach effort from the COS. For the latter, a physics-themed booth on the main quad is staffed by students and faculty. The department constructs new equipment for the booth each year, designed to interest the lay public. Past themes have included *Cooking with magnets: Secrets of induction* (2013) and *Defying gravity: Physics of levitation* (2014). "Physics Open Day" is being skipped in 2018 to give recently hired faculty time to complete their labs and to give us time to re-imagine different formats for this event.

In 2012 the physics department accepted an offer to contract with Tucson Unified School District (TUSD) to enhance the knowledge of their K-5 teachers in the physical sciences. This was a major undertaking, requiring original curriculum development and around 60 hours of workshop-style instruction for each of two groups of teachers (a total of 30). Faculty Manne and graduate student Felix Kling led this effort, developing the curriculum in early 2013 and initiating the first set of workshops in summer 2013. Feedback from the participating teachers was highly positive, and there was hope for a follow-up program in 2015. However, TUSD did not complete the necessary administrative steps for this to go forward.

Another new endeavor pursued is an annual "High School Day", which is targeted to local high school seniors taking physics. This event is intended to advertise the work being done here both to local students and high school physics teachers, with the goal of recruiting new undergraduates to our program. The event functions as a field trip for the students, during which they visit our department for presentations from faculty members and lab tours. In the initial iterations of this event (in 2014 and 2015) physics students from a small number of highly regarded Tucson high schools were invited. Unfortunately, there was no resulting increase in the fraction of students from these high schools that enrolled in our program. Changes to the High School Day are presently being considered that might increase its effectiveness, such as targeting a broader cross-section of local high schools.

In addition to the above initiatives that have been started since the previous APR, the department continues several longstanding outreach efforts. Among these is the successful Research Experience for Undergraduates (REU) program funded by the NSF. The program was started by faculty Robert Thews in 1993 in collaboration with faculty Tony Pitucco of Pima Community College (PCC). The program places promising PCC students in summer research labs at UA in order to ease their transition to the university. Many of these students are from nontraditional backgrounds and from underrepresented populations in physics. The summer internship gives them a "research home" upon transfer, increasing retention and success rates. About 70% of students continue working in their research labs after the summer REU ends, and over 90% earn their 4-year degree. Faculty Manne, the current PI, recently received word that the REU program manager will recommend continued funding for the program for three more years (though the funding decision is not yet final).

Physics Phun Nite is another longstanding outreach effort. In this annual event, an evening "show" is performed where members of the department (faculty, postdocs, students, and staff members) show their favorite physics demos. This is open to all interested members of the public, and typically elementary and middle-school children compose a large fraction of the audience. To keep the pace lively, there is little explanation of the physics behind the demonstrations, but the hope is that seeing the demonstrations will spark a curiosity for further study in the minds of the audience. Typical attendance for this event is 150-200 people.

Our department also benefits from the significant outreach efforts of the Women in Physics (WiP) Club, which is organized by graduate students with membership open to all physicists (from undergraduate through faculty) in our department. One of the club's missions is to promote physics as a potential career path to students from elementary through high school age, and to further this mission the group organizes several outings to schools in the Tucson area where physics concepts are demonstrated. The group also participates in judging science fair projects at local schools.

The university's COS holds a lecture series focused on a particular area of science each spring. In 2016, the topic of choice was "Rethinking Reality", and faculty members Dienes, Gralla, and Cheu (as well as emeritus faculty member Meystre) presented lectures. These were enormously popular, with the 2600 seat Centennial Hall auditorium filled to capacity and 1000 more filled seats in overflow rooms. These lectures generated considerable publicity online and in Arizona, and resulted in:

- YouTube videos with nearly 200,000 combined downloads over the past year
- Interviews on National Public Radio as local segments during "Science Friday"
- Interviews in local newspapers, including the Arizona Daily Star
- Numerous subsequent private showings to interested science groups/clubs across southern Arizona

K Collaboration with Other Units

The physics department maintains dynamic collaborations with other units on campus including the departments of applied math (a graduate interdisciplinary program (GIDP)) , astronomy, biochemistry, chemistry, planetary sciences, and the College of Optical Sciences. Most of these connections are at the individual investigator level. The current department head meets regularly with the heads of astronomy, planetary sciences and chemistry to explore coherence in hiring, potential interdisciplinary proposals, and education.

K.1 Collaborations in Research

The physics department includes eight faculty members whose active research interests include astrophysics and/or cosmology (Cheu, Dienes, Gralla, Johns, Melia, Rafelski, Sarcevic, Su). Interaction with the astronomy department is facilitated by the Theoretical Astrophysics Program (TAP), which hosts a colloquium series and awards small grants and prizes to members and their students. The mission of TAP is to foster connections between the departments of physics, astronomy and planetary science. The bi-weekly colloquia are well-attended by members of all three departments, providing regular interaction opportunities.

The physics department recently completed a joint faculty hire with astronomy to begin in 2018, Dr. Elisabeth Krause (75% astronomy and 25% physics). The physics department also participated in the search and hire of TAP candidate Vasilis Paschalidis, who has chosen astronomy as his home department with a joint appointment in physics department.

Sarcevic and Su served on the TAP faculty search committee in 2013, which resulted in the hiring of Gralla. Sarcevic served on two astronomy department faculty search committees (in 2013 and 2016) and Gralla and Sarcevic served on the TAP faculty search committee in 2016. Rozo served on a different astronomy department faculty search committee in 2016. Sarcevic also served on the astronomy department promotion and tenure committee for three years.

Gralla is initiating a research collaboration with Dimitrios Psaltis and Feryal Ozel from the astronomy department. Rozo currently collaborates with astronomy postdoctoral fellow Anna Patej. Rozo's weekly group meeting is attended by astronomy graduate student Christine O'Donnell and LSST staff member Keith Bechtol. Physics graduate student Ashoordin Ashoormaram is a student of astronomy professor Ann Zabludoff and Rozo serves on his Ph.D. committee.

Modern biological research has found that physical forces and processes are essential to proper biological function. Therefore, the field of biophysics has become crucial to advancing the biological sciences over the last twenty years. Wolgemuth and Visscher hold joint appointments in the molecular and cellular biology (MCB) department and in the applied mathematics GIDP. Both of these faculty members pursue interdisciplinary research that analyzes the role of physics in biology.

As one of the founders of the Biological Physics Program (BPP), Visscher, who also holds a joint appointment in the COOS, has frequent interactions with faculty in the life sciences. He has also served on faculty search committees and graduate dissertation committees for the MCB department. Over the last two years, Visscher has been on leave working at Inscopix to broaden his research expertise into the fields of neuroscience and imaging.

In order to strengthen the department's presence in biological physics, Wolgemuth was hired from the department of cell biology at the University of Connecticut Health Center in 2012. He has graduated two Ph.D. students in MCB and is currently advising 2 others. He a research member in the cancer biology GIDP and has an active collaboration with Dr. Jesse Martinez's group to study the role of physics in lung cancer metastasis. Wolgemuth is also a collaborator in the Physical Science of Oncology Center that is located at Johns Hopkins University (PI: Denis Wirtz).

In addition to research, Visscher and Wolgemuth alternate in teaching a course on biological physics

(PHYS 431/531). This course is cross-listed between physics and neuroscience and routinely enrolls 20-30 students from a broad range of departments, including physics, neuroscience, chemistry and biochemistry, engineering, ecology and evolutionary biology, and MCB.

Several members of the physics department are also affiliated members of the applied math program. In practical terms, this affiliation facilitates collaborative interactions between faculty in these units and permits and encourages the physics faculty members' supervision of research by applied math students. As an example of an important outcome of this interdisciplinary connection, Melia (in physics) and Maier (in Math) have published several influential papers on the use of statistical methods for model selection in cosmology. This work has demonstrated the growing tension between the predictions of the current standard model and the ever-improving measurements now being carried out by ground- and space-based missions. Another example is that two physics graduate students in the Wolgemuth lab (Scott Sawyer and Jorge Palos-Chavez) are currently supported by the Computational and Mathematical Modeling of Biomedical Systems NIH training grant that is administered by the applied math graduate program.

In 2009, a chemical physics program was added as a new specialty program. This is an interdisciplinary track that enables students to pursue cutting edge research at the boundaries of physics and chemistry. Students in the program have worked in diverse fields such as nanoscience, biological physics, and astrochemistry. The program recognizes the high impact such an interdisciplinary and collaborative program can bring to solving modern research problems. This flexible program allows students to take core courses from both the physics and chemistry departments. Several faculty from the chemistry and biochemistry department hold courtesy joint appointments in physics, and a number of graduate students have been involved in crossover Ph.D. dissertation research under the supervision of faculty from the partner department.

Several physics faculty have active collaborations with faculty members from the COOS, and have held joint grants, or have supervised Ph.D. students from the COOS. Physics faculty members Cronin, Mazumdar, Sandhu, and Visscher hold courtesy joint appointments in the COOS. Similarly COOS faculty Brian Anderson, Rolf Binder, Charles Falco, Poul Jessen and Ewan Wright hold courtesy joint appointments in physics and have mentored physics students. In 2016-17, physics and optical sciences faculty conducted joint faculty searches in the general area of Atomic, Molecular, and Optical physics (AMO) physics. This collaboration allowed bringing in larger than the usual number of candidates for interviews and led to the hiring of physics assistant professor Mohammed Hassan.

Finally the Professional Science Masters (PSM) program in medical physics is a joint program between the physics and radiation oncology departments. Students complete course work in both departments and are well prepared for American Board of Radiology (ABR) certification or to enter a residency program in medical physics.

L Faculty Planning

L.1 Faculty's Collective View of the Program's Future

The challenges facing the department and the opportunities they present have already been discussed in Section B under "Unit Goals". In order to avoid duplications, this section presents primarily details concerning the implementations of these goals and focusing on the means to achieve them. As with Section B this section was prepared following consultations with the entire faculty.

L.1.1 Student Engagement

The challenges here include (i) increasing student credit hours at a time when the demographics are going to be unfavorable, (ii) increasing enrollment and retention of under-represented minorities (URM) and women as physics majors, and (iii) making physics graduates aware of career opportunities outside of traditional academics. It is emphasized that these are not completely disparate issues. Careful planning and judicious use of resources will help us address them synergistically.

A successful applied physics program, for instance, should increase overall student credit hours, URM enrollment in physics, and post-graduation success in obtaining a technical job. In order to meet the above challenges the department plans to continue to improve the quality of our undergraduate education. The focus will be on continued innovation and active learning in the large service courses as well as the introductory courses for physics majors. It is expected that successes at this level will then migrate to upper division courses, and this has already begun to occur. More emphasis on practical applications of physics will also be essential.

It was very recently announced the UA earned official designation as a Hispanic-Serving Institution (HSI). This makes us only one of three institutions that are an HSI and simultaneously a member of the Association of American Universities. The department hopes to utilize this significant designation to improve our recruitment of Hispanic physics students.

Currently about ten faculty members are involved in teaching the large enrollment service courses. Our plan is to increase this number by about 50%. Teaching assignments for faculty are made on a rotating basis within the physics department, so that no instructor teaches the same course in consecutive semesters, or more than three consecutive years. Taken together with sabbatical leaves, a larger number of excellent instructors for the introductory courses will be essential to obtain the desired results. Again it is expected that the methods used in these courses will be used in upper division courses when those faculty teach them.

Faculty will be encouraged to attend meetings organized by UA Faculty Learning Communities (FLC) (`http://academicaffairs.arizona.edu/uali`). Roughly ten faculty members have already attended them. The department also hopes to create an intradepartmental FLC that will meet bi-weekly to discuss implementation of new engagement strategies and effectiveness of the various approaches.

The department already conducts peer evaluations of teaching where the goal currently is to give suggestions for improvements to colleagues. Eventually these evaluations may be used for measuring annual faculty performance. The department also puts strong emphasis on success in classroom instruction in deciding on its reward structure. An added incentive will be to give time off from teaching every fourth semester for successful teaching of introductory courses, where "success" is measured in terms of student feedback, performance, and retention.

A more ambitious goal currently is to create a freshman level one-unit course for majors that teaches students about various careers for physicists in the private sector. Materials for the course will be taken from the APS website (APS Joint Task Force on Undergraduate Physics Programs (JTUPP) and Forum on Industrial and Applied Physics (FIAP),). The course will be seminar-based in part, with seminar speakers coming from Tucson and Phoenix-based corporations. With the large number of optics-based corporations in the greater Tucson area we are confident of finding a sufficient number of UA physics and optical sciences alumni who will agree to speak. Additional speakers will be invited from the Industrial Speakers List of the APS (http://www.aps.org/careers/advisors/speakers.cfm). Depending on the success of this course, as determined from the opinions of students, a similar course for graduate students may be created at a later time.

L.1.2 Faculty Hiring and Innovation

Two different essential hiring plans have already been presented in Section B. The goals are to reach a target number of 32-36 faculty members over the next five years and to reach an experimentalist:theorist ratio of 3:2 from the current ratio of 1:1. Two fruitful searches each year will be needed to achieve these goals, given expected retirements.

All of these will need substantial resources from the College of Science (COS) and the UA. Significant resources must also come from departmental ICR, since 25% of faculty start up funds must come from the department. Our target is to increase average grant funding per faculty member by about 20% over the next five years. This should be achievable even in these times of tight federal funding with proper incentives. Currently, faculty members do not receive any return on the ICR they generate. ICR return for discretionary spending will be offered to faculty who are most successful at obtaining funding. Teaching relief will be granted to faculty members who are writing grants to establish large research centers or other significant collaborative projects.

A different challenge facing the department in the near future is the faculty age distribution. While the primary target in faculty hiring is to increase the proportion of experimentalists, it is recognized that the average age of theorists in the department, especially in the particle-nuclear theory and condensed matter theory groups, is getting to be unacceptably high. In the absence of corrective measures taken in the near future, in about five to ten years the department will be facing an opposite crisis, a severe paucity of theorists. In addition to the hirings discussed in Section B, the department plans to hire younger theorists in both these research areas. With two hires per year, this is an achievable plan.

Appendices

A Peer Teaching Evaluation

Proposal for Observing Faculty Teaching

We are generally following the protocol for peer review of teaching developed for use at UA. Information on the protocol can be found here: http://teachingprotocol.oia.arizona.edu/content/2

The peer review will involve

A pre-observation meeting to discuss the target class and goals for the review,

A classroom observation and review of the course syllabus and D2L site,

A post-observation meeting to discuss the observer's feedback.

Each faculty will be visited twice, roughly half in the spring and half in the fall. This will require expanding the current teaching evaluation committee by several members. Our thinking is that two visits by different observers provides better information than one visit.

The classroom visitations will be announced and pre-arranged between instructor and observer.

For the first two years, the evaluations will be for constructive feedback only and not used as part of CAPE. They will not be shared with the Head during this period.

The observers will comment on the items listed below. A short summary will be written and discussed with the instructor along with comments on the items on this list. Again, the comments are intended for constructive feedback for the instructor.

Items used in the classroom observation

Presented clear class objectives and presented topics in a logical sequence.

Paced lesson appropriately.

Spoke extemporaneously, did not read continually from notes.

Wrote clearly and legibly on a white board, overhead projector or other technology.

Demonstrated command of the subject matter.

Presented examples to clarify points.

If possible, related new ideas to familiar concepts.

Asked questions, with adequate wait time, to monitor students' understanding or performance.

Maintained student attention.

Treated students with respect.

Provided opportunities for the students to apply lecture content in class.

Supported the lesson with useful examples, classroom discussion and activities.

Used active-learning or collaborative learning methodology in the course.

What fraction of the course period was spent on activities other than lecturing?

What do you think the students learned from this lesson?

What were the instructor's major strengths demonstrated in this class session?

What suggestions do you have for improving this instructor's teaching?

B TCE Teaching Evaluations

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-561-001 : Physics of Semiconductors (60% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.67	1.15	2.07 - 5.27	No
Difficulty level of the course	3.33	1.53	1.22 - 5.45	No
	3.67	1.53	1.55 - 5.78	No
	4.33	0.58	3.53 - 5.13	No
Overall instructor comparison	3.67	1.15	2.07 - 5.27	No
Overall rating of teaching effectiveness	4.00	1.00	2.61 - 5.39	No
Overall rating of the course	3.67	1.15	2.07 - 5.27	No
Students treated with respect	5.00	0.00	5	No
Usefulness of course materials	4.00	1.73	1.6 - 6.4	No
Usefulness of the in-class activities	4.67	0.58	3.87 - 5.47	No
Usefulness of the outside assignments	4.00	1.00	2.61 - 5.39	No
Value of time spent on course	4.67	0.58	3.87 - 5.47	No

[redacted]

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-140-002 : Introductory Mechanics (83.33% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	2.60	1.14	1.48 - 3.72	No
Difficulty level of the course	3.80	1.30	2.52 - 5.08	No
	4.00	1.73	2.3 - 5.7	No
	4.40	0.89	3.52 - 5.28	No
Overall instructor comparison	2.60	1.14	1.48 - 3.72	No
Overall rating of teaching effectiveness	3.00	1.41	1.61 - 4.39	No
Overall rating of the course	2.40	0.89	1.52 - 3.28	No
Students treated with respect	4.00	1.22	2.8 - 5.2	No
Usefulness of course materials	3.80	1.10	2.73 - 4.87	No
Usefulness of the in-class activities	2.80	1.30	1.52 - 4.08	No
Usefulness of the outside assignments	3.60	1.14	2.48 - 4.72	No
Value of time spent on course	3.60	1.14	2.48 - 4.72	No [redacted]

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-001 : Introductory Mechanics (83.33% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.20	0.95	2.77 - 3.63	No
Difficulty level of the course	4.20	0.89	3.8 - 4.6	No
	4.25	0.79	3.9 - 4.6	No
	4.30	0.73	3.97 - 4.63	No
Overall instructor comparison	2.50	1.32	1.91 - 3.09	No
Overall rating of teaching effectiveness	2.75	0.97	2.32 - 3.18	No
Overall rating of the course	2.35	1.18	1.82 - 2.88	No
Students treated with respect	4.00	1.03	3.54 - 4.46	No
Usefulness of course materials	3.65	0.93	3.23 - 4.07	No
Usefulness of the in-class activities	2.65	0.99	2.21 - 3.09	No
Usefulness of the outside assignments	3.15	0.81	2.78 - 3.52	No
Value of time spent on course	3.30	1.03	2.84 - 3.76	No [redacted]

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-012 : Introductory Mechanics (95.45% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined S[redacted]
Amount learned	2.95	1.12	2.46 - 3.44	No
Difficulty level of the course	3.71	0.96	3.3 - 4.13	No
	3.95	1.02	3.5 - 4.4	No
		1.07	3.48 - 4.42	No
Overall instructor comparison	2.81	1.33	2.23 - 3.39	No
Overall rating of teaching effectiveness	3.19	1.33	2.61 - 3.77	No
Overall rating of the course	2.57	1.08	2.1 - 3.04	No
Students treated with respect	4.19	0.98	3.76 - 4.62	No
Usefulness of course materials	3.63	1.21	3.1 - 4.16	No
Usefulness of the in-class activities	3.05	1.39	2.44 - 3.66	No
Usefulness of the outside assignments	3.80	1.36	3.2 - 4.4	No
Value of time spent on course	3.14	1.28	2.58 - 3.7	No

Instructor[redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-013 : Introductory Mechanics (70.83% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	2.76	1.20	2.18 - 3.35	No [redacted]
Difficulty level of the course	4.35	0.79	3.97 - 4.74	No
	4.47	1.07	3.95 - 4.99	No
	4.65	0.70	4.3 - 4.99	No
Overall instructor comparison	2.53	1.42	1.83 - 3.22	No
Overall rating of teaching effectiveness	2.65	1.54	1.89 - 3.4	No
Overall rating of the course	2.12	1.22	1.52 - 2.71	No
Students treated with respect	3.82	1.07	3.3 - 4.35	No
Usefulness of course materials	3.69	1.01	3.19 - 4.18	No
Usefulness of the in-class activities	2.82	1.42	2.13 - 3.52	No
Usefulness of the outside assignments	3.24	1.15	2.67 - 3.8	No
Value of time spent on course	3.24	1.09	2.7 - 3.77	No

Instructor: [redacted]Term: Spring 2017 Session: 1 Course: PHYS-141-014 : Introductory Mechanics (83.33% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.00	1.03	3.54 - 4.46	No [redacted]
Difficulty level of the course	4.30	0.86	3.91 - 4.69	No
	4.40	0.68	4.09 - 4.71	No
	4.60	0.60	4.33 - 4.87	No
Overall instructor comparison	3.15	1.46	2.49 - 3.81	No
Overall rating of teaching effectiveness	3.50	1.28	2.93 - 4.07	No
Overall rating of the course	3.10	1.45	2.45 - 3.75	No
Students treated with respect	4.50	0.76	4.16 - 4.84	No
Usefulness of course materials	3.63	1.30	3.05 - 4.22	No
Usefulness of the in-class activities	3.55	1.23	2.99 - 4.11	No
Usefulness of the outside assignments	3.60	1.19	3.07 - 4.13	No
Value of time spent on course	3.65	1.14	3.14 - 4.16	No

Instructor: [redacted]rm: Spring 2017 Session: 1 Course: PHYS-141-015 : Introductory Mechanics (90.48% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	2.84	1.07	2.35 - 3.34	No [redacted]

	4.29	0.56	4.04 - 4.53	No
Overall instructor comparison	2.86	1.42	2.23 - 3.48	No
Overall rating of teaching effectiveness	3.05	1.53	2.38 - 3.72	No
Overall rating of the course	2.86	1.28	2.3 - 3.42	No
Students treated with respect	3.95	1.24	3.41 - 4.5	No
Usefulness of course materials	3.95	1.20	3.43 - 4.48	No
Usefulness of the in-class activities	2.95	1.36	2.36 - 3.55	No
Usefulness of the outside assignments	3.52	1.36	2.93 - 4.12	No
Value of time spent on course	3.95	1.02	3.5 - 4.4	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-019 : Introductory Mechanics (87.5% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.36	0.84	2.9 - 3.81	No
Difficulty level of the course	3.86	0.77	3.44 - 4.28	No
	4.07	0.92	3.57 - 4.57	No
	4.21	0.80	3.78 - 4.65	No
Overall instructor comparison	3.21	1.19	2.57 - 3.86	No
Overall rating of teaching effectiveness	3.43	1.16	2.8 - 4.06	No
Overall rating of the course	3.00	1.36	2.26 - 3.74	No
Students treated with respect	4.29	0.91	3.79 - 4.78	No
Usefulness of course materials	3.79	1.12	3.18 - 4.4	No
Usefulness of the in-class activities	3.29	1.49	2.48 - 4.1	No
Usefulness of the outside assignments	3.86	1.03	3.3 - 4.42	No
Value of time spent on course	3.36	1.08	2.77 - 3.95	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-020 : Introductory Mechanics (66.67% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.79	1.19	3.14 - 4.43	No
Difficulty level of the course	4.00	1.11	3.4 - 4.6	No
	4.14	1.03	3.58 - 4.7	No
	4.50	1.09	3.91 - 5.09	No
Overall instructor comparison	3.86	1.17	3.22 - 4.49	No
Overall rating of teaching effectiveness	3.86	0.95	3.34 - 4.37	No
Overall rating of the course	3.36	1.01	2.81 - 3.91	No
Students treated with respect	4.29	1.07	3.7 - 4.87	No
Usefulness of course materials	4.00	1.18	3.36 - 4.64	No
Usefulness of the in-class activities	3.86	1.41	3.09 - 4.62	No
Usefulness of the outside assignments	3.86	1.23	3.19 - 4.53	No
Value of time spent on course	3.71	1.14	3.1 - 4.33	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-021 : Introductory Mechanics (68.42% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.46	1.13	2.82 - 4.1	No
Difficulty level of the course	4.31	0.95	3.77 - 4.84	No
	4.38	0.96	3.84 - 4.93	No
Overall instructor comparison	3.00	1.29	2.27 - 3.73	No
Overall rating of teaching effectiveness	3.15	1.28	2.43 - 3.88	No

Difficulty level of the course	3.79	1.23	3.22 - 4.36	No
	3.95	0.78	3.59 - 4.31	No
	4.05	1.03	3.58 - 4.53	No
Overall instructor comparison	2.58	1.26	2 - 3.16	No
Overall rating of teaching effectiveness	2.84	1.26	2.26 - 3.42	No
Overall rating of the course	2.42	1.22	1.86 - 2.98	No
Students treated with respect	3.84	1.30	3.24 - 4.44	No
Usefulness of course materials	3.79	1.27	3.2 - 4.38	No
Usefulness of the in-class activities	2.95	1.51	2.25 - 3.64	No
Usefulness of the outside assignments	3.95	0.97	3.5 - 4.4	No
Value of time spent on course	3.11	1.24	2.53 - 3.68	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-016 : Introductory Mechanics (77.27% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.24	1.09	2.7 - 3.77	No
Difficulty level of the course	4.41	0.71	4.06 - 4.76	No
	4.47	0.72	4.12 - 4.82	No
	4.82	0.39	4.63 - 5.02	No
Overall instructor comparison	3.12	1.22	2.52 - 3.71	No
Overall rating of teaching effectiveness	3.18	1.33	2.52 - 3.83	No
Overall rating of the course	2.88	1.22	2.29 - 3.48	No
Students treated with respect	4.24	1.03	3.73 - 4.74	No
Usefulness of course materials	3.75	1.13	3.2 - 4.3	No
Usefulness of the in-class activities	3.41	1.18	2.84 - 3.99	No
Usefulness of the outside assignments	3.53	1.23	2.93 - 4.13	No
Value of time spent on course	3.65	1.11	3.1 - 4.19	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-017 : Introductory Mechanics (72.73% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.06	1.12	3.49 - 4.63	No
Difficulty level of the course	4.50	0.73	4.13 - 4.87	No
		0.89	4.05 - 4.95	No
	4.69	0.48	4.45 - 4.93	No
Overall instructor comparison	3.63	1.09	3.07 - 4.18	No
Overall rating of teaching effectiveness	4.19	0.98	3.69 - 4.68	No
Overall rating of the course	3.56	1.03	3.04 - 4.08	No
Students treated with respect	4.63	0.50	4.37 - 4.88	No
Usefulness of course materials	4.06	1.06	3.52 - 4.6	No
Usefulness of the in-class activities	4.25	0.68	3.9 - 4.6	No
Usefulness of the outside assignments	4.25	0.86	3.82 - 4.68	No
Value of time spent on course	4.19	0.98	3.69 - 4.68	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-018 : Introductory Mechanics (91.3% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.48	0.81	3.12 - 3.83	No
Difficulty level of the course	3.90	0.83	3.54 - 4.27	No
	4.10	1.09	3.62 - 4.57	No

Overall rating of teaching effectiveness	4.56	1.01	3.85 - 5.26	No
Overall rating of the course	4.44	0.73	3.94 - 4.95	No
Students treated with respect	4.67	0.50	4.32 - 5.01	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-182-012 : Introductory Laboratory II (66.67% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.86	1.10	3.26 - 4.45	No
Overall rating of teaching effectiveness	4.21	0.89	3.73 - 4.7	No
Overall rating of the course	3.79	1.05	3.21 - 4.36	No
Students treated with respect	4.93	0.27	4.78 - 5.07	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-579A-001 : Advanced Relativistic Quantum Mechanics I (61.11

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.73	0.79	3.24 - 4.21	No
Difficulty level of the course	3.73	0.90	3.17 - 4.29	No
	4.18	0.75	3.72 - 4.65	No
Overall instructor comparison	3.64	0.67	3.22 - 4.05	No
Overall rating of teaching effectiveness	4.27	0.65	3.87 - 4.67	No
Overall rating of the course	4.09	0.54	3.76 - 4.43	No
Students treated with respect	5.00	0.00	5	No
Usefulness of course materials	4.09	1.04	3.44 - 4.74	No
Usefulness of the in-class activities	4.55	0.52	4.22 - 4.87	No
Usefulness of the outside assignments	4.64	0.50	4.32 - 4.95	No
Value of time spent on course	4.36	0.81	3.86 - 4.87	No

Instructor[redacted] Term: Spring 2017 Session: 1 Course: PHYS-569-001 : Introduction to General Relativity (54.55% Respons

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.50	0.55	4.02 - 4.98	No
Difficulty level of the course	3.33	0.52	2.88 - 3.79	No
	3.50	0.55	3.02 - 3.98	No
	3.67	0.52	3.21 - 4.12	No
Overall instructor comparison	4.67	0.52	4.21 - 5.12	No
Overall rating of teaching effectiveness	4.83	0.41	4.48 - 5.19	No
Overall rating of the course	4.67	0.52	4.21 - 5.12	No
Students treated with respect	5.00	0.00	5	No
Usefulness of course materials	4.50	0.84	3.77 - 5.23	No
Usefulness of the in-class activities	5.00	0.00	5	No
Usefulness of the outside assignments	4.83	0.41	4.48 - 5.19	No
Value of time spent on course	4.83	0.41	4.48 - 5.19	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-103-001 : Introductory Physics II (54.58% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.05	0.85	3.9 - 4.19	No
Difficulty level of the course	3.98	0.83	3.84 - 4.13	No
	4.02	0.86	3.87 - 4.17	No

Overall rating of the course	2.54	1.05	1.94 - 3.13	No
Students treated with respect	4.08	0.95	3.54 - 4.62	No
Usefulness of course materials	3.31	1.25	2.6 - 4.02	No
Usefulness of the in-class activities	3.23	1.17	2.57 - 3.89	No
Usefulness of the outside assignments	3.15	0.99	2.6 - 3.71	No
Value of time spent on course	3.67	1.15	3.01 - 4.32	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-022 : Introductory Mechanics (88.89% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.63	1.09	3.07 - 4.18	No
Difficulty level of the course	4.25	0.68	3.9 - 4.6	No
	4.56	0.51	4.3 - 4.82	No
Overall instructor comparison	3.19	1.11	2.63 - 3.75	No
Overall rating of teaching effectiveness	3.63	1.09	3.07 - 4.18	No
Overall rating of the course	3.06	1.12	2.49 - 3.63	No
Students treated with respect	4.25	0.93	3.78 - 4.72	No
Usefulness of course materials	3.50	1.21	2.89 - 4.11	No
Usefulness of the in-class activities	3.81	1.17	3.22 - 4.4	No
Usefulness of the outside assignments	3.38	1.26	2.74 - 4.01	No
Value of time spent on course	3.56	0.89	3.11 - 4.01	No

Instructor [redacted]n Term: Spring 2017 Session: 1 Course: PHYS-261H-001 : Honors Introductory Electricity and Magnetism (83.72

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.92	1.05	3.57 - 4.27	No
Difficulty level of the course	4.17	0.88	3.88 - 4.46	No
		1.03	3.83 - 4.51	No
	4.50	0.70	4.27 - 4.73	No
Overall instructor comparison	3.86	1.20	3.46 - 4.26	No
Overall rating of teaching effectiveness	4.08	1.02	3.74 - 4.42	No
Overall rating of the course	3.56	1.32	3.12 - 3.99	No
Students treated with respect	4.61	0.55	4.43 - 4.79	No
Usefulness of course materials	3.77	1.19	3.38 - 4.17	No
Usefulness of the in-class activities	4.17	1.18	3.77 - 4.56	No
Usefulness of the outside assignments	4.03	1.04	3.68 - 4.37	No
Value of time spent on course	4.17	1.03	3.83 - 4.51	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-182-007 : Introductory Laboratory II (53.33% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.13	1.13	3.29 - 4.96	No
Overall rating of teaching effectiveness	4.25	1.16	3.39 - 5.11	No
Overall rating of the course	3.88	0.99	3.14 - 4.61	No
Students treated with respect	4.63	0.74	4.07 - 5.18	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-182-011 : Introductory Laboratory II (56.25% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.22	0.67	3.76 - 4.68	No

	4.04	0.83	3.9 - 4.18	No
Overall instructor comparison	4.27	0.89	4.12 - 4.43	No
Overall rating of teaching effectiveness	4.49	0.82	4.35 - 4.63	No
Overall rating of the course	3.91	0.97	3.74 - 4.08	No
Students treated with respect	4.60	0.66	4.49 - 4.72	No
Usefulness of course materials	4.03	1.03	3.86 - 4.21	No
Usefulness of the in-class activities	4.53	0.74	4.41 - 4.66	No
Usefulness of the outside assignments	4.43	0.83	4.28 - 4.57	No
Value of time spent on course	4.29	0.94	4.13 - 4.45	No

Instructor: [redacted]Term: Spring 2017 Session: 1 Course: PHYS-162H-001 : Honors Introductory Optics and Thermodynamic

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.15	0.88	3.76 - 4.54	No
Difficulty level of the course	3.70	0.86	3.31 - 4.09	No
	3.75	0.79	3.4 - 4.1	No
		0.91	3.34 - 4.16	No
Overall instructor comparison	4.65	0.49	4.43 - 4.87	No
Overall rating of teaching effectiveness	4.80	0.41	4.62 - 4.98	No
Overall rating of the course	4.25	0.72	3.93 - 4.57	No
Students treated with respect	4.80	0.41	4.62 - 4.98	No
Usefulness of course materials	4.40	0.82	4.03 - 4.77	No
Usefulness of the in-class activities	4.70	0.57	4.44 - 4.96	No
Usefulness of the outside assignments	4.65	0.49	4.43 - 4.87	No
Value of time spent on course	4.80	0.41	4.62 - 4.98	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-105A-001 : Introduction to Scientific Computing (83.33% Res

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.80	1.32	3.11 - 4.49	No
Overall rating of teaching effectiveness	4.07	1.03	3.53 - 4.61	No
Overall rating of the course	3.80	1.26	3.14 - 4.46	No
Students treated with respect	4.60	0.63	4.27 - 4.93	No

Instructor [redacted]erm: Spring 2017 Session: 1 Course: PHYS-105A-002 : Introduction to Scientific Computing (75% Respo

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.56	0.73	4.05 - 5.06	No
Overall rating of teaching effectiveness	4.67	0.50	4.32 - 5.01	No
Overall rating of the course	4.33	0.71	3.84 - 4.82	No
Students treated with respect	4.89	0.33	4.66 - 5.12	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-181-002 : Introductory Laboratory I (50% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.00	0.94	3.38 - 4.62	No
Overall rating of teaching effectiveness	4.30	0.95	3.68 - 4.92	No
Overall rating of the course	3.90	0.88	3.33 - 4.47	No
Students treated with respect	4.50	0.53	4.16 - 4.84	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-181-007 : Introductory Laboratory I (50% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.55	0.93	2.97 - 4.12	No
Overall rating of teaching effectiveness	4.09	0.94	3.51 - 4.68	No
Overall rating of the course	3.64	1.03	3 - 4.27	No
Students treated with respect	4.45	0.52	4.13 - 4.78	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-181-010 : Introductory Laboratory I (50% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.75	0.87	3.24 - 4.26	No
Overall rating of teaching effectiveness	4.33	0.89	3.81 - 4.86	No [redacted]
Overall rating of the course	3.92	1.00	3.33 - 4.51	No
Students treated with respect	4.83	0.39	4.6 - 5.06	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-102-001A : Introductory Physics I (68.31% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.92	0.90	3.74 - 4.1	No
Overall rating of teaching effectiveness	4.28	0.89	4.1 - 4.46	No
Overall rating of the course	3.85	1.02	3.65 - 4.06	No
Students treated with respect	4.68	0.49	4.58 - 4.78	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-102-002A : Introductory Physics I (73.94% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.93	0.89	3.76 - 4.1	No
Overall rating of teaching effectiveness	4.30	0.82	4.15 - 4.46	No
Overall rating of the course	4.03	0.83	3.87 - 4.19	No [redacted]
Students treated with respect	4.52	0.77	4.38 - 4.67	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-263H-001 : Honors Introductory Relativity and Quantum Phys

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	2.95	1.19	2.41 - 3.49	No
Difficulty level of the course	3.40	0.75	3.06 - 3.74	No [redacted]
		0.82	3.03 - 3.77	No
	3.75	0.85	3.37 - 4.13	No
Overall instructor comparison	2.30	1.08	1.81 - 2.79	No
Overall rating of teaching effectiveness	2.65	1.31	2.06 - 3.24	No
Overall rating of the course	2.75	1.12	2.25 - 3.25	No
Students treated with respect	4.65	0.59	4.39 - 4.91	No
Usefulness of course materials	3.53	1.06	3.06 - 4.01	No [redacted]
Usefulness of the in-class activities	2.95	1.27	2.38 - 3.52	No
Usefulness of the outside assignments	3.65	1.04	3.18 - 4.12	No
Value of time spent on course	3.15	0.99	2.71 - 3.59	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-200-001 : The Science of Good Cooking (34.86% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.68	1.23	3.29 - 4.08	No
Difficulty level of the course	3.39	0.89	3.11 - 3.68	No
	3.65	0.89	3.36 - 3.94	No
	3.79	0.70	3.56 - 4.02	No
Overall instructor comparison	3.42	1.06	3.08 - 3.76	No
Overall rating of teaching effectiveness	4.05	1.06	3.71 - 4.4	No
Overall rating of the course	3.66	0.94	3.36 - 3.96	No
Students treated with respect	4.68	0.53	4.51 - 4.85	No
Usefulness of course materials	3.87	1.21	3.48 - 4.26	No
Usefulness of the in-class activities	3.92	1.17	3.54 - 4.3	No
Usefulness of the outside assignments	3.84	1.15	3.47 - 4.21	No
Value of time spent on course	3.79	1.04	3.45 - 4.13	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-142-001 : Introductory Optics and Thermodynamics (5

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.47	1.07	2.95 - 3.99	No
Difficulty level of the course	4.12	0.78	3.73 - 4.5	No
	4.47	0.72	4.12 - 4.82	No
		0.80	4.08 - 4.86	No
Overall instructor comparison	2.47	1.37	1.8 - 3.14	No
Overall rating of teaching effectiveness	2.88	1.22	2.29 - 3.48	No
Overall rating of the course	2.47	1.23	1.87 - 3.07	No
Students treated with respect	3.65	1.32	3 - 4.29	No
Usefulness of course materials	3.53	1.13	2.98 - 4.08	No
Usefulness of the in-class activities	3.19	1.47	2.47 - 3.91	No
Usefulness of the outside assignments	3.82	1.13	3.27 - 4.38	No
Value of time spent on course	3.65	1.22	3.05 - 4.25	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-143-001 : Introductory Optics and Thermodynamics (5

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	2.91	1.18	2.56 - 3.26	No
Difficulty level of the course	4.13	1.08	3.81 - 4.45	No
	4.27	0.94	3.99 - 4.54	No
	4.33	0.83	4.09 - 4.58	No
Overall instructor comparison	2.05	0.81	1.81 - 2.28	No
Overall rating of teaching effectiveness	2.41	1.00	2.11 - 2.7	No
Overall rating of the course	2.05	0.71	1.83 - 2.26	No
Students treated with respect	3.58	1.16	3.24 - 3.92	No
Usefulness of course materials	3.55	1.04	3.24 - 3.86	No
Usefulness of the in-class activities	2.68	1.20	2.33 - 3.04	No
Usefulness of the outside assignments	3.55	1.21	3.19 - 3.9	No
Value of time spent on course	3.00	1.24	2.63 - 3.37	No

Instructor [redacted] Term: Spring 2017 Session: 1 Course: PHYS-371-001 : Quantum Theory (56.52% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag

Amount learned	3.77	0.73	3.36 - 4.18	No [redacted]
Difficulty level of the course	3.92	0.76	3.49 - 4.35	No
	4.08	0.64	3.71 - 4.44	No
	4.15	0.69	3.76 - 4.54	No
Overall instructor comparison	3.85	1.21	3.16 - 4.53	No
Overall rating of teaching effectiveness	3.92	1.26	3.21 - 4.63	No
Overall rating of the course	3.77	1.17	3.11 - 4.43	No
Students treated with respect	4.62	0.51	4.33 - 4.9	No
Usefulness of course materials	4.36	0.67	3.98 - 4.75	No
Usefulness of the in-class activities	4.31	0.75	3.88 - 4.73	No
Usefulness of the outside assignments	4.54	0.52	4.24 - 4.83	No
Value of time spent on course	4.62	0.51	4.33 - 4.9	No

Instructor: [redacted]Term: Spring 2017 Session: 1 Course: PHYS-371-002 : Quantum Theory (72.73% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.50	0.76	3.94 - 5.06	No [redacted]
Difficulty level of the course	3.38	0.74	2.82 - 3.93	No
	3.88	0.83	3.26 - 4.49	No
Overall instructor comparison	4.43	0.98	3.71 - 5.15	No
Overall rating of teaching effectiveness	4.86	0.38	4.58 - 5.14	No
Overall rating of the course	4.57	0.79	3.99 - 5.15	No
Students treated with respect	4.88	0.35	4.61 - 5.14	No
Usefulness of course materials	4.50	0.84	3.88 - 5.12	No
Usefulness of the in-class activities	4.38	0.52	3.99 - 4.76	No
Usefulness of the outside assignments	4.88	0.35	4.61 - 5.14	No
Value of time spent on course	4.71	0.49	4.35 - 5.08	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-469-001 : Introduction to General Relativity (27.78% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.20	1.10	3.13 - 5.27	No
Difficulty level of the course	3.20	1.10	2.13 - 4.27	No [redacted]
	3.40	1.14	2.28 - 4.52	No
	3.80	1.10	2.73 - 4.87	No
Overall instructor comparison	4.80	0.45	4.36 - 5.24	No
Overall rating of teaching effectiveness	5.00	0.00	5	No
Overall rating of the course	4.60	0.55	4.06 - 5.14	No
Students treated with respect	4.80	0.45	4.36 - 5.24	No
Usefulness of course materials	4.00	1.15	2.87 - 5.13	No
Usefulness of the in-class activities	5.00	0.00	5	No
Usefulness of the outside assignments	5.00	0.00	5	No
Value of time spent on course	4.80	0.45	4.36 - 5.24	No

Instructor: [redacted]A Term: Spring 2017 Session: 1 Course: PHYS-240-002A : Introductory Electricity and Magnetism (57.14% Re

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.25	0.96	3.17 - 5.33	No
Overall rating of teaching effectiveness	4.00	0.82	3.08 - 4.92	No [redacted]
Overall rating of the course	4.00	0.82	3.08 - 4.92	No

Students treated with respect	4.25	0.50	3.68 - 4.82	No

Instructor: [redacted] A Term: Spring 2017 Session: 1 Course: PHYS-241-001A : Introductory Electricity and Magnetism (39.62% Re

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.69	1.16	3.34 - 4.04	No
Overall rating of teaching effectiveness	3.55	1.09	3.22 - 3.88	No
Overall rating of the course	3.50	1.09	3.17 - 3.83	No
Students treated with respect	4.19	0.89	3.92 - 4.46	No

Instructor: [redacted] A Term: Spring 2017 Session: 1 Course: PHYS-241-002A : Introductory Electricity and Magnetism (41.82% Re

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.80	1.02	3.5 - 4.1	No
Overall rating of teaching effectiveness	3.83	1.10	3.5 - 4.15	No
Overall rating of the course	3.83	0.90	3.56 - 4.09	No
Students treated with respect	4.22	0.81	3.98 - 4.46	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-305-001 : Computational Physics (37.5% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.33	1.00	2.64 - 4.03	No
Difficulty level of the course	3.44	1.01	2.74 - 4.15	No
	3.56	0.73	3.05 - 4.06	No
	3.78	1.09	3.02 - 4.54	No
Overall instructor comparison	3.56	1.24	2.7 - 4.41	No
Overall rating of teaching effectiveness	3.78	0.97	3.1 - 4.45	No
Overall rating of the course	3.33	1.58	2.24 - 4.43	No
Students treated with respect	5.00	0.00	5	No
Usefulness of course materials	3.89	1.36	2.94 - 4.83	No
Usefulness of the in-class activities	3.56	0.88	2.94 - 4.17	No
Usefulness of the outside assignments	3.78	0.67	3.32 - 4.24	No
Value of time spent on course	3.44	1.33	2.52 - 4.37	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-105A-001 : Introduction to Scientific Computing (83.33% Resp

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.80	1.32	3.11 - 4.49	No
Overall rating of teaching effectiveness	4.07	1.03	3.53 - 4.61	No
Overall rating of the course	3.80	1.26	3.14 - 4.46	No
Students treated with respect	4.60	0.63	4.27 - 4.93	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-002 : Introductory Mechanics (92.31% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.29	1.08	2.85 - 3.73	No
Difficulty level of the course	4.04	1.04	3.62 - 4.47	No
	4.08	1.18	3.6 - 4.56	No
	4.42	0.72	4.12 - 4.71	No
Overall instructor comparison	3.21	1.18	2.73 - 3.69	No

Overall rating of teaching effectiveness	3.54	1.06	3.11 - 3.98	No
Overall rating of the course	2.83	1.09	2.39 - 3.28	No
Students treated with respect	4.33	0.87	3.98 - 4.69	No
Usefulness of course materials	3.21	1.22	2.71 - 3.7	No
Usefulness of the in-class activities	3.42	1.32	2.88 - 3.95	No
Usefulness of the outside assignments	3.00	1.06	2.57 - 3.43	No
Value of time spent on course	3.33	0.87	2.98 - 3.69	No

Instructor[redacted]Term: Spring 2017 Session: 1 Course: PHYS-141-003 : Introductory Mechanics (92% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Se[redacted]tion Flag
Amount learned	2.96	0.98	2.55 - 3.36	No
Difficulty level of the course	3.70	0.97	3.29 - 4.1	No
	3.91	0.73	3.61 - 4.22	No
	3.96	0.82	3.61 - 4.3	No
Overall instructor comparison	3.09	1.12	2.62 - 3.56	No
Overall rating of teaching effectiveness	3.52	1.04	3.09 - 3.96	No
Overall rating of the course	2.96	1.02	2.53 - 3.38	No
Students treated with respect	3.83	1.03	3.4 - 4.26	No
Usefulness of course materials	3.04	1.15	2.56 - 3.52	No
Usefulness of the in-class activities	3.43	1.16	2.95 - 3.92	No
Usefulness of the outside assignments	2.91	0.95	2.52 - 3.31	No
Value of time spent on course	3.43	0.90	3.06 - 3.81	No

Instructor[redacted]Term: Spring 2017 Session: 1 Course: PHYS-141-004 : Introductory Mechanics (69.57% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.00	0.97	3.51 - 4.49	No
Difficulty level of the course	4.06	0.77	3.67 - 4.45	No
		1.00	3.56 - 4.57	No
	4.31	0.79	3.91 - 4.71	No
Overall instructor comparison	3.63	1.26	2.99 - 4.26	No
Overall rating of teaching effectiveness	4.00	1.15	3.42 - 4.58	No
Overall rating of the course	3.81	1.17	3.22 - 4.4	No
Students treated with respect	4.19	1.17	3.6 - 4.78	No
Usefulness of course materials	3.73	1.28	3.09 - 4.38	No
Usefulness of the in-class activities	4.00	1.03	3.48 - 4.52	No
Usefulness of the outside assignments	3.50	1.41	2.78 - 4.22	No
Value of time spent on course	3.56	1.15	2.98 - 4.15	No

Instructor[redacted]o Term: Spring 2017 Session: 1 Course: PHYS-141-005 : Introductory Mechanics (82.61% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.26	1.15	2.73 - 3.79	No
Difficulty level of the course	4.21	0.71	3.88 - 4.54	No
	4.26	1.05	3.78 - 4.75	No
	4.37	0.90	3.95 - 4.78	No
Overall instructor comparison	2.84	1.21	2.28 - 3.4	No
Overall rating of teaching effectiveness	3.37	1.07	2.88 - 3.86	No
Overall rating of the course	2.84	1.26	2.26 - 3.42	No

Usefulness of the in-class activities	3.47	1.19	2.84 - 4.09	No
Usefulness of the outside assignments	2.93	0.96	2.43 - 3.44	No
Value of time spent on course	3.27	0.96	2.76 - 3.77	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-141-009 : Introductory Mechanics (73.91% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.88	0.86	3.46 - 4.3	No [redacted]
Difficulty level of the course	4.00	1.17	3.43 - 4.57	No
	4.29	0.69	3.96 - 4.63	No
	4.56	0.63	4.25 - 4.87	No
Overall instructor comparison	3.50	1.26	2.88 - 4.12	No
Overall rating of teaching effectiveness	3.81	1.28	3.19 - 4.44	No
Overall rating of the course	3.44	1.26	2.82 - 4.06	No
Students treated with respect	4.29	0.85	3.88 - 4.71	No
Usefulness of course materials	3.76	1.09	3.23 - 4.3	No
Usefulness of the in-class activities	3.82	1.33	3.17 - 4.48	No
Usefulness of the outside assignments	3.00	1.32	2.35 - 3.65	No
Value of time spent on course	3.81	0.83	3.4 - 4.22	No

Instructor [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-010 : Introductory Mechanics (72.22% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.31	1.44	2.49 - 4.12	No [redacted]
Difficulty level of the course	3.85	1.28	3.12 - 4.57	No
	4.08	1.26	3.37 - 4.79	No
	4.15	1.14	3.51 - 4.8	No
Overall instructor comparison	3.00	1.29	2.27 - 3.73	No
Overall rating of teaching effectiveness	3.54	1.05	2.94 - 4.13	No
Overall rating of the course	3.15	1.14	2.51 - 3.8	No
Students treated with respect	4.46	0.66	4.09 - 4.84	No
Usefulness of course materials	3.25	1.22	2.56 - 3.94	No
Usefulness of the in-class activities	3.46	0.88	2.97 - 3.96	No
Usefulness of the outside assignments	3.46	1.13	2.82 - 4.1	No
Value of time spent on course	3.46	1.13	2.82 - 4.1	No

Instructor [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-011 : Introductory Mechanics (73.33% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.36	1.21	2.62 - 4.11	No [redacted]
Difficulty level of the course	3.91	1.22	3.15 - 4.67	No
	4.00	1.18	3.27 - 4.73	No
	4.18	1.25	3.41 - 4.96	No
Overall instructor comparison	3.55	1.51	2.61 - 4.48	No
Overall rating of teaching effectiveness	3.91	1.38	3.06 - 4.76	No
Overall rating of the course	3.36	1.57	2.39 - 4.33	No
Students treated with respect	4.18	1.25	3.41 - 4.96	No
Usefulness of course materials	4.20	1.03	3.56 - 4.84	No
Usefulness of the in-class activities	3.80	1.32	2.98 - 4.62	No
Usefulness of the outside assignments	3.90	0.99	3.28 - 4.52	No

Students treated with respect	4.16	0.76	3.8 - 4.51	No
Usefulness of course materials	3.32	1.20	2.76 - 3.87	No
Usefulness of the in-class activities	3.68	1.16	3.15 - 4.22	No
Usefulness of the outside assignments	3.26	1.41	2.61 - 3.91	No
Value of time spent on course	3.42	1.07	2.93 - 3.92	No

Instructor [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-006 : Introductory Mechanics (85.71% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.50	0.86	3.09 - 3.91	No
Difficulty level of the course	3.83	0.92	3.39 - 4.27	No
	3.89	1.02	3.4 - 4.38	No
	4.17	0.71	3.83 - 4.5	No
Overall instructor comparison	3.39	0.98	2.92 - 3.85	No
Overall rating of teaching effectiveness	3.94	0.94	3.5 - 4.39	No
Overall rating of the course	3.11	0.96	2.65 - 3.57	No
Students treated with respect	4.22	1.06	3.72 - 4.73	No
Usefulness of course materials	3.39	1.24	2.8 - 3.98	No
Usefulness of the in-class activities	3.78	1.00	3.3 - 4.25	No
Usefulness of the outside assignments	3.83	1.04	3.34 - 4.33	No
Value of time spent on course	4.06	0.87	3.64 - 4.47	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-007 : Introductory Mechanics (75% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.67	1.08	3.15 - 4.18	No
Difficulty level of the course	4.17	0.71	3.83 - 4.5	No
	4.22	0.81	3.84 - 4.61	No
	4.56	0.70	4.22 - 4.89	No
Overall instructor comparison	3.61	1.20	3.04 - 4.18	No
Overall rating of teaching effectiveness	3.83	0.99	3.37 - 4.3	No
Overall rating of the course	2.89	0.90	2.46 - 3.32	No
Students treated with respect	4.61	0.61	4.32 - 4.9	No
Usefulness of course materials	3.50	1.10	2.98 - 4.02	No
Usefulness of the in-class activities	4.06	1.00	3.58 - 4.53	No
Usefulness of the outside assignments	3.56	1.25	2.96 - 4.15	No
Value of time spent on course	3.72	1.07	3.21 - 4.23	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-008 : Introductory Mechanics (68.18% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.27	0.88	2.8 - 3.73	No
Difficulty level of the course	3.73	0.80	3.31 - 4.15	No
		0.88	3.27 - 4.2	No
		0.96	3.23 - 4.24	No
Overall instructor comparison	2.73	1.10	2.16 - 3.31	No
Overall rating of teaching effectiveness	3.47	0.92	2.99 - 3.95	No
Overall rating of the course	3.00	0.93	2.52 - 3.48	No
Students treated with respect	4.13	0.83	3.7 - 4.57	No
Usefulness of course materials	2.93	1.16	2.32 - 3.54	No

Value of time spent on course	3.45	1.57	2.48 - 4.43	No

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-023 : Introductory Mechanics (76.47% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.08	1.32	2.33 - 3.82	No
Difficulty level of the course	3.77	1.36	3 - 4.54	No
	4.31	0.85	3.82 - 4.79	No
	4.38	0.51	4.1 - 4.67	No
Overall instructor comparison	2.85	1.41	2.05 - 3.64	No
Overall rating of teaching effectiveness	3.23	1.36	2.46 - 4	No
Overall rating of the course	2.85	1.21	2.16 - 3.53	No
Students treated with respect	4.38	0.65	4.02 - 4.75	No
Usefulness of course materials	3.83	0.94	3.3 - 4.36	No
Usefulness of the in-class activities	3.54	1.13	2.9 - 4.18	No
Usefulness of the outside assignments	3.46	1.27	2.75 - 4.18	No
Value of time spent on course	3.54	1.13	2.9 - 4.18	No

Instructor [redacted] Term: Spring 2017 Session: 1 Course: PHYS-141-024 : Introductory Mechanics (81.25% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.77	0.93	3.24 - 4.29	No
Difficulty level of the course	4.08	0.64	3.71 - 4.44	No
		0.95	3.54 - 4.62	No
	4.23	0.60	3.89 - 4.57	No
Overall instructor comparison	3.15	0.69	2.76 - 3.54	No
Overall rating of teaching effectiveness	3.62	0.77	3.18 - 4.05	No
Overall rating of the course	3.00	0.91	2.48 - 3.52	No
Students treated with respect	3.92	0.86	3.44 - 4.41	No
Usefulness of course materials	3.00	1.41	2.2 - 3.8	No
Usefulness of the in-class activities	3.69	1.11	3.06 - 4.32	No
Usefulness of the outside assignments	2.69	1.25	1.98 - 3.4	No
Value of time spent on course	3.62	1.19	2.94 - 4.29	No

Instructor [redacted]erm: Spring 2017 Session: 1 Course: PHYS-204-001 : Mathematical Techniques in Physics (60% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.20	0.86	2.75 - 3.65	No
Difficulty level of the course	3.93	0.70	3.56 - 4.3	No
	4.07	0.80	3.65 - 4.49	No
	4.13	0.64	3.8 - 4.47	No
Overall instructor comparison	3.13	0.99	2.61 - 3.65	No
Overall rating of teaching effectiveness	3.53	0.83	3.1 - 3.97	No
Overall rating of the course	2.87	1.19	2.24 - 3.49	No
Students treated with respect	4.40	0.63	4.07 - 4.73	No
Usefulness of course materials	4.07	0.73	3.69 - 4.45	No
Usefulness of the in-class activities	3.87	0.83	3.43 - 4.3	No
Usefulness of the outside assignments	3.80	1.01	3.27 - 4.33	No
Value of time spent on course	3.87	0.92	3.39 - 4.35	No

Instructor:[redacted]Term: Spring 2017 Session: 1 Course: PHYS-305-001 : Computational Physics (37.5% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined [redacted]tion Flag
Amount learned	3.33	1.00	2.64 - 4.03	No
Difficulty level of the course	3.44	1.01	2.74 - 4.15	No
	3.56	0.73	3.05 - 4.06	No
	3.78	1.09	3.02 - 4.54	No
Overall instructor comparison	3.56	1.24	2.7 - 4.41	No
Overall rating of teaching effectiveness	3.78	0.97	3.1 - 4.45	No
Overall rating of the course	3.33	1.58	2.24 - 4.43	No
Students treated with respect	5.00	0.00	5	No
Usefulness of course materials	3.89	1.36	2.94 - 4.83	No
Usefulness of the in-class activities	3.56	0.88	2.94 - 4.17	No
Usefulness of the outside assignments	3.78	0.67	3.32 - 4.24	No
Value of time spent on course	3.44	1.33	2.52 - 4.37	No

Instructor:[redacted]A Term: Spring 2017 Session: 1 Course: PHYS-161H-001 : Honors Introductory Mechan[redacted]68.75% R[redacted]spo

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.33	1.24	2.9 - 3.76	No
Difficulty level of the course	4.12	0.86	3.82 - 4.42	No
	4.42	0.75	4.16 - 4.68	No
	4.48	0.67	4.25 - 4.72	No
Overall instructor comparison	2.55	1.25	2.11 - 2.98	No
Overall rating of teaching effectiveness	2.85	1.20	2.43 - 3.26	No
Overall rating of the course	2.73	1.13	2.34 - 3.12	No
Students treated with respect	3.94	0.90	3.63 - 4.25	No
Usefulness of course materials	3.66	1.14	3.26 - 4.05	No
Usefulness of the in-class activities	3.30	1.29	2.86 - 3.75	No
Usefulness of the outside assignments	3.79	1.17	3.38 - 4.19	No
Value of time spent on course	3.58	1.12	3.19 - 3.96	No

Instructor:[redacted]Term: Spring 2017 Session: 1 Course: PHYS-570B-001 : Quantum Mechanics (90% Response)[redacted]

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.61	0.50	3.37 - 3.85	No
Difficulty level of the course	3.39	0.61	3.1 - 3.68	No
	3.44	0.51	3.2 - 3.69	No
	3.56	0.51	3.31 - 3.8	No
Overall instructor comparison	4.00	0.84	3.6 - 4.4	No
Overall rating of teaching effectiveness	4.50	0.62	4.21 - 4.79	No
Overall rating of the course	4.00	0.77	3.64 - 4.36	No
Students treated with respect	4.72	0.57	4.45 - 5	No
Usefulness of course materials	4.56	0.62	4.26 - 4.85	No
Usefulness of the in-class activities	4.50	0.71	4.16 - 4.84	No
Usefulness of the outside assignments	4.39	0.78	4.02 - 4.76	No
Value of time spent on course	4.28	0.75	3.92 - 4.64	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-515A-001 : Electromagnetic Theory (65% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.69	1.03	3.11 - 4.28	No
Difficulty level of the course	4.00	0.91	3.48 - 4.52	No
	4.23	0.83	3.76 - 4.7	No
	4.38	0.77	3.95 - 4.82	No
Overall instructor comparison	3.85	1.21	3.16 - 4.53	No
Overall rating of teaching effectiveness	4.08	1.04	3.49 - 4.66	No
Overall rating of the course	3.69	1.18	3.02 - 4.36	No
Students treated with respect	4.62	0.51	4.33 - 4.9	No
Usefulness of course materials	4.15	1.28	3.43 - 4.88	No
Usefulness of the in-class activities	4.31	0.75	3.88 - 4.73	No
Usefulness of the outside assignments	4.38	0.96	3.84 - 4.93	No
Value of time spent on course	3.92	1.04	3.34 - 4.51	No [redacted]

Instructor: [redacted] Term: Spring 2017 Session: 1 Course: PHYS-460-001 : Solid-State Physics (62.5% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.40	0.55	3.86 - 4.94	No
Difficulty level of the course	3.80	0.84	2.98 - 4.62	No
	4.00	0.71	3.31 - 4.69	No
		1.00	3.02 - 4.98	No
Overall instructor comparison	4.20	1.30	2.92 - 5.48	No
Overall rating of teaching effectiveness	4.40	0.89	3.52 - 5.28	No
Overall rating of the course	4.40	0.89	3.52 - 5.28	No
Students treated with respect	4.80	0.45	4.36 - 5.24	No
Usefulness of course materials	5.00	0.00	5	No
Usefulness of the in-class activities	5.00	0.00	5	No
Usefulness of the outside assignments	4.60	0.55	4.06 - 5.14	No
Value of time spent on course	4.60	0.55	4.06 - 5.14	No

Instructor: [redacted]erm: Spring 2017 Session: 1 Course: PHYS-431-001 : Molecular Biophysics (58.33% Respons

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.86	1.35	2.78 - 4.93	No
Difficulty level of the course	2.29	0.76	1.68 - 2.89	No
	2.57	0.53	2.14 - 3	No
	2.86	0.69	2.3 - 3.41	No
Overall instructor comparison	4.71	0.49	4.32 - 5.1	No
Overall rating of teaching effectiveness	4.71	0.49	4.32 - 5.1	No
Overall rating of the course	4.43	0.79	3.8 - 5.06	No
Students treated with respect	4.86	0.38	4.55 - 5.16	No
Usefulness of course materials	4.67	0.52	4.25 - 5.08	No
Usefulness of the in-class activities	4.71	0.49	4.32 - 5.1	No
Usefulness of the outside assignments	4.43	0.53	4 - 4.86	No
Value of time spent on course	4.29	1.25	3.28 - 5.29	No

Instructor: Zhang,Shufeng Term: Spring 2017 Session: 1 Course: PHYS-331-001 : Electricity and Magnetism I (26.32% Response)

Question Category	Mean	St. Dev	95% Conf Int	Com[redacted]ection Flag
Amount learned	3.40	0.55	2.86 - 3.94	No
Difficulty level of the course	4.00	1.00	3.02 - 4.98	No
	4.20	0.84	3.38 - 5.02	No
Overall instructor comparison	3.00	0.71	2.31 - 3.69	No
Overall rating of teaching effectiveness	3.00	0.71	2.31 - 3.69	No
Overall rating of the course	3.20	0.45	2.76 - 3.64	No
Students treated with respect	4.00	1.00	3.02 - 4.98	No
Usefulness of course materials	4.25	0.96	3.31 - 5.19	No
Usefulness of the in-class activities	3.20	0.84	2.38 - 4.02	No
Usefulness of the outside assignments	3.60	0.55	3.06 - 4.14	No
Value of time spent on course	3.80	0.84	2.98 - 4.62	No

Instructor:[redacted] Term: Spring 2017 Session: 1 Course: PHYS-331-002 : Electricity and Magnetism I (37.5% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	2.33	0.58	1.53 - 3.13	No [redacted]
Difficulty level of the course	4.00	1.00	2.61 - 5.39	No
	4.33	0.58	3.53 - 5.13	No
Overall instructor comparison	2.67	0.58	1.87 - 3.47	No
Overall rating of teaching effectiveness	4.00	1.00	2.61 - 5.39	No
Overall rating of the course	2.33	0.58	1.53 - 3.13	No
Students treated with respect	4.67	0.58	3.87 - 5.47	No
Usefulness of course materials	4.00	1.00	2.61 - 5.39	No
Usefulness of the in-class activities	3.67	1.15	2.07 - 5.27	No
Usefulness of the outside assignments	3.00	2.00	.23 - 5.77	No
Value of time spent on course	3.67	1.15	2.07 - 5.27	No

[redacted]

Instructor: [redacted] Term: Fall 2017 Session: 1 Course: PHYS-263H-001 : Honors Introductory Relativity and Quantum Physics

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.54	0.75	4.12 - 4.96	No
Difficulty level of the course	4.08	0.62	3.73 - 4.43	No
	4.23	0.58	3.91 - 4.56	No
		0.89	3.73 - 4.73	No
Overall instructor comparison	4.85	0.36	4.64 - 5.05	No
Overall rating of teaching effectiveness	4.85	0.36	4.64 - 5.05	No
Overall rating of the course	4.54	0.50	4.26 - 4.82	No
Students treated with respect	4.85	0.53	4.54 - 5.15	No
Usefulness of course materials	4.77	0.42	4.53 - 5.01	No
Usefulness of the in-class activities	4.85	0.36	4.64 - 5.05	No
Usefulness of the outside assignments	4.75	0.43	4.51 - 5	No
Value of time spent on course	4.85	0.36	4.64 - 5.05	No

Instructo[redacted] Term: Fall 2017 Session: 1 Course: PHYS-204-001 : Mathematical Techniques in Physics (55% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.64	1.07	2.97 - 4.3	No
Difficulty level of the course	3.18	0.94	2.6 - 3.76	No
	3.55	0.66	3.14 - 3.95	No
	3.82	0.72	3.37 - 4.26	No
Overall instructor comparison	3.09	1.08	2.42 - 3.76	No
Overall rating of teaching effectiveness	3.91	0.67	3.5 - 4.32	No
Overall rating of the course	3.18	0.94	2.6 - 3.76	No
Students treated with respect	4.73	0.45	4.45 - 5	No
Usefulness of course materials	1.80	0.75	1.34 - 2.26	No
Usefulness of the in-class activities	4.09	0.67	3.68 - 4.5	No
Usefulness of the outside assignments	3.45	0.99	2.84 - 4.07	No
Value of time spent on course	4.18	0.72	3.74 - 4.63	No

Instructor: [redacted] Term: Fall 2017 Session: 1 Course: PHYS-103-001 : Introductory Physics II (49.42% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.61	0.99	3.4 - 3.82	No
Difficulty level of the course	3.93	0.86	3.74 - 4.11	No
	3.99	0.88	3.8 - 4.18	No
	4.05	0.85	3.86 - 4.23	No
Overall instructor comparison	3.80	1.15	3.55 - 4.05	No
Overall rating of teaching effectiveness	4.12	1.03	3.9 - 4.34	No
Overall rating of the course	3.56	1.20	3.31 - 3.82	No
Students treated with respect	4.66	0.54	4.54 - 4.78	No
Usefulness of course materials	3.94	1.02	3.72 - 4.15	No
Usefulness of the in-class activities	4.26	0.99	4.05 - 4.47	No
Usefulness of the outside assignments	4.19	0.95	3.98 - 4.39	No
Value of time spent on course	4.11	0.97	3.9 - 4.31	No

Instructor: [redacted]m: Fall 2017 Session: 1 Course: PHYS-511-001 : Analytical Mechanics (95.24% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag

Amount learned	4.05	0.74	3.72 - 4.38	No
Difficulty level of the course	3.05	0.74	2.72 - 3.38	No
	3.15	0.57	2.89 - 3.41	No
	3.25	0.70	2.94 - 3.56	No
Overall instructor comparison	4.50	0.67	4.2 - 4.8	No
Overall rating of teaching effectiveness	4.80	0.51	4.57 - 5.03	No
Overall rating of the course	4.50	0.74	4.17 - 4.83	No
Students treated with respect	4.95	0.22	4.85 - 5.05	No
Usefulness of course materials	4.85	0.48	4.64 - 5.06	No
Usefulness of the in-class activities	4.80	0.40	4.62 - 4.98	No
Usefulness of the outside assignments	4.90	0.30	4.77 - 5.03	No
Value of time spent on course	4.70	0.46	4.49 - 4.91	No

Instructor [redacted] Term: Fall 2017 Session: 1 Course: PHYS-161H-001 : Honors Introductory Mecha

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.67	1.14	3.2 - 4.13	No
Difficulty level of the course	4.21	1.12	3.75 - 4.66	No
	4.29	0.84	3.95 - 4.64	No
	4.50	0.82	4.17 - 4.83	No
Overall instructor comparison	3.63	0.90	3.26 - 3.99	No
	3.92	0.70	3.63 - 4.2	No
Overall rating of teaching effectiveness	3.71	0.79	3.39 - 4.03	No
	4.08	0.76	3.77 - 4.39	No
Overall rating of the course	3.42	1.08	2.98 - 3.86	No
Students treated with respect	4.58	0.64	4.32 - 4.84	No
Usefulness of course materials	4.11	1.05	3.68 - 4.54	No
Usefulness of the in-class activities	4.29	0.84	3.95 - 4.64	No
Usefulness of the outside assignments	4.17	0.94	3.78 - 4.55	No
Value of time spent on course	4.08	0.95	3.69 - 4.47	No

Instructor: [redacted] Term: Fall 2017 Session: 1 Course: PHYS-305-001 : Computational Physics (53.85% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.36	0.89	3.87 - 4.84	No
Difficulty level of the course	3.71	0.80	3.28 - 4.15	No
	3.79	0.94	3.27 - 4.3	No
	4.07	0.70	3.69 - 4.45	No
Overall instructor comparison	4.36	0.89	3.87 - 4.84	No
Overall rating of teaching effectiveness	4.50	0.63	4.16 - 4.84	No
Overall rating of the course	4.14	1.12	3.53 - 4.75	No
Students treated with respect	4.86	0.35	4.67 - 5.05	No
Usefulness of course materials	4.25	0.72	3.86 - 4.64	No
Usefulness of the in-class activities	4.62	0.62	4.28 - 4.96	No
Usefulness of the outside assignments	4.14	0.74	3.74 - 4.55	No
Value of time spent on course	4.36	0.89	3.87 - 4.84	No

Instructor: Rozo,Eduardo Term: Fall 2017 Session: 1 Course: PHYS-162H-001 : Honors Introductory Optics and Thermodynamics (84.2

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag

Amount learned	4.19	0.68	3.95 - 4.43	No
Difficulty level of the course	4.03	0.73	3.77 - 4.29	No
	4.31	1.01	3.96 - 4.67	No
	4.50	0.75	4.24 - 4.76	No
Overall instructor comparison	4.25	0.87	3.95 - 4.55	No
Overall rating of teaching effectiveness	4.47	0.75	4.2 - 4.73	No
Overall rating of the course	3.94	0.97	3.6 - 4.28	No
Students treated with respect	4.69	0.53	4.5 - 4.87	No
Usefulness of course materials	4.44	0.61	4.22 - 4.65	No
Usefulness of the in-class activities	4.53	0.71	4.28 - 4.78	No
Usefulness of the outside assignments	4.09	0.80	3.81 - 4.38	No
Value of time spent on course	4.34	0.69	4.1 - 4.59	No

Instructor[redacted]Term: Fall 2017 Session: 1 Course: PHYS-695A-001 : Current Problems in Physics (62.5% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.60	1.02	2.93 - 4.27	No
Difficulty level of the course	2.70	1.49	1.73 - 3.67	No
Overall instructor comparison	3.60	1.02	2.93 - 4.27	No
Overall rating of teaching effectiveness	4.00	0.89	3.42 - 4.58	No
Overall rating of the course	3.60	0.92	3 - 4.2	No
Students treated with respect	4.60	0.66	4.17 - 5.03	No
Usefulness of the in-class activities	4.30	0.90	3.71 - 4.89	No
Usefulness of the outside assignments	4.43	0.73	3.95 - 4.9	No
Value of time spent on course	4.00	1.26	3.17 - 4.83	No

Instructor: [redacted] Term: Fall 2017 Session: 1 Course: PHYS-161H-001 : Honors Introductory Mechanics (64.86% Respo

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.67	1.14	3.2 - 4.13	No
Difficulty level of the course	4.21	1.12	3.75 - 4.66	No
	4.29	0.84	3.95 - 4.64	No
	4.50	0.82	4.17 - 4.83	No
Overall instructor comparison	3.63	0.90	3.26 - 3.99	No
	3.92	0.70	3.63 - 4.2	No
Overall rating of teaching effectiveness	4.08	0.76	3.77 - 4.39	No
	4.54	0.58	4.31 - 4.78	No
Overall rating of the course	3.42	1.08	2.98 - 3.86	No
Students treated with respect	4.58	0.64	4.32 - 4.84	No
Usefulness of course materials	4.11	1.05	3.68 - 4.54	No
Usefulness of the in-class activities	4.29	0.84	3.95 - 4.64	No
Usefulness of the outside assignments	4.17	0.94	3.78 - 4.55	No
Value of time spent on course	4.08	0.95	3.69 - 4.47	No

Instructor[redacted] R Term: Fall 2017 Session: 1 Course: PHYS-320-001 : Optics (30% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.67	0.75	3.01 - 4.32	No
Difficulty level of the course	3.33	0.94	2.51 - 4.16	No
	3.50	1.12	2.52 - 4.48	No

	3.67	0.75	3.01 - 4.32	No
Overall instructor comparison	4.00	0.82	3.28 - 4.72	No
Overall rating of teaching effectiveness	4.17	0.69	3.56 - 4.77	No
Overall rating of the course	3.83	0.90	3.05 - 4.62	No
Students treated with respect	4.67	0.47	4.25 - 5.08	No
Usefulness of course materials	4.17	0.90	3.38 - 4.95	No
Usefulness of the in-class activities	4.33	0.75	3.68 - 4.99	No
Usefulness of the outside assignments	4.33	0.94	3.51 - 5.16	No
Value of time spent on course	4.33	0.47	3.92 - 4.75	No

Instructor[redacted] A Term: Fall 2017 Session: 1 Course: PHYS-528-001 : Statistical Mechanics (73.68% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.00	0.85	3.54 - 4.46	No
Difficulty level of the course	3.71	0.70	3.33 - 4.09	No
	3.79	0.67	3.42 - 4.15	No
		0.77	3.37 - 4.21	No
Overall instructor comparison	3.93	0.88	3.45 - 4.41	No
Overall rating of teaching effectiveness	4.50	0.73	4.1 - 4.9	No
Overall rating of the course	4.00	0.76	3.59 - 4.41	No
Students treated with respect	4.86	0.35	4.67 - 5.05	No
Usefulness of course materials	3.23	1.48	2.43 - 4.03	No
Usefulness of the in-class activities	4.62	0.49	4.35 - 4.88	No
Usefulness of the outside assignments	4.77	0.42	4.54 - 5	No
Value of time spent on course	4.50	0.73	4.1 - 4.9	No

Instructor[redacted]erm: Fall 2017 Session: 1 Course: PHYS-570A-001 : Quantum Mechanics (94.44% Response)

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.06	0.73	3.7 - 4.41	No
Difficulty level of the course	3.59	0.77	3.21 - 3.97	No
	3.71	0.82	3.3 - 4.11	No
	3.94	0.73	3.59 - 4.3	No
Overall instructor comparison	4.06	0.87	3.63 - 4.49	No
Overall rating of teaching effectiveness	4.53	0.61	4.23 - 4.83	No
Overall rating of the course	4.12	0.90	3.68 - 4.56	No
Students treated with respect	4.76	0.42	4.56 - 4.97	No
Usefulness of course materials	4.76	0.42	4.56 - 4.97	No
Usefulness of the in-class activities	4.47	0.61	4.17 - 4.77	No
Usefulness of the outside assignments	4.75	0.43	4.54 - 4.96	No
Value of time spent on course	4.65	0.48	4.41 - 4.88	No

Instructor:[redacted]Term: Fall 2017 Session: 1 Course: PHYS-579B-001 : Advanced Relativistic Quantum Mechanics II (62.5

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	4.80	0.40	4.41 - 5.19	No
Difficulty level of the course	4.20	0.75	3.47 - 4.93	No
	4.40	0.49	3.92 - 4.88	No
Overall instructor comparison	5.00	0.00	5	No
Overall rating of teaching effectiveness	4.80	0.40	4.41 - 5.19	No

Overall rating of the course	4.80	0.40	4.41 - 5.19	No
Students treated with respect	5.00	0.00	5	No
Usefulness of course materials	4.80	0.40	4.41 - 5.19	No
Usefulness of the in-class activities	4.80	0.40	4.41 - 5.19	No
Usefulness of the outside assignments	4.80	0.40	4.41 - 5.19	No
Value of time spent on course	4.80	0.40	4.41 - 5.19	No

Instructor: [redacted]erm: Fall 2017 Session: 1 Course: PHYS-261H-001 : Honors Introductory Electricity and Magnetism (5

Question Category	Mean	St. Dev	95% Conf Int	Combined Section Flag
Amount learned	3.82	0.94	3.42 - 4.22	No
Difficulty level of the course	4.32	0.76	3.99 - 4.64	No
	4.50	0.72	4.19 - 4.81	No
	4.59	0.49	4.38 - 4.8	No
Overall instructor comparison	3.55	1.16	3.05 - 4.04	No
Overall rating of teaching effectiveness	3.82	1.11	3.34 - 4.29	No
Overall rating of the course	3.36	1.23	2.84 - 3.89	No
Students treated with respect	4.68	0.47	4.48 - 4.88	No
Usefulness of course materials	4.00	1.05	3.55 - 4.45	No
Usefulness of the in-class activities	4.18	0.72	3.88 - 4.49	No
Usefulness of the outside assignments	4.23	0.73	3.91 - 4.54	No
Value of time spent on course	4.09	0.79	3.75 - 4.43	No

Combined Sections:

Term: Fall 2017 Session: 1 Course: PHYS 142/143 001 [redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	3.75	1.75	3.67 - 3.83
Amount learned	2.98	1.11	2.78 - 3.18
Difficulty level of the course	4.33	0.88	4.23 - 4.43
Overall instructor comparison	2.72	1.31	2.54 - 2.90
Overall rating of teaching effectiveness	3.00	1.39	2.82 - 3.18
Overall rating of the course	2.30	1.19	2.08 - 2.52
Students treated with respect	4.18	0.92	4.02 - 4.34
Usefulness of course materials	3.53	1.32	3.28 - 3.78
Usefulness of the in-class activities	3.10	1.34	2.86 - 3.34
Usefulness of the outside assignments	3.68	1.15	3.46 - 3.90
Value of time spent on course	3.20	1.23	2.98 - 3.42

Term: Fall 2017 Session: 1 Course: PHYS 321 001/002 [redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	4.41	2.20	4.06 - 4.76
Amount learned	4.23	0.73	3.84 - 4.62
Difficulty level of the course	4.18	0.72	3.94 - 4.42
Overall instructor comparison	4.23	0.73	3.84 - 4.62
Overall rating of teaching effectiveness	4.46	0.66	4.11 - 4.81
Overall rating of the course	4.31	0.75	3.90 - 4.72

Students treated with respect	4.77	0.60	4.44 - 5.00
Usefulness of course materials	4.00	0.93	3.35 - 4.65
Usefulness of the in-class activities	4.31	0.75	3.90 - 4.72
Usefulness of the outside assignments	4.38	0.77	3.97 - 4.79
Value of time spent on course	4.46	0.88	3.99 - 4.93

Term: Fall 2017 Session: 1 Course: PHYS 331 001/002[redacted]

[redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	4.48	2.14	4.15 - 4.81
Amount learned	4.50	0.52	4.23 - 4.77
Difficulty level of the course	4.45	0.59	4.27 - 4.63
Overall instructor comparison	4.79	0.43	4.57 - 5.00
Overall rating of teaching effectiveness	4.79	0.43	4.57 - 5.00
Overall rating of the course	4.50	0.76	4.11 - 4.89
Students treated with respect	4.93	0.27	4.79 - 5.00
Usefulness of course materials	4.14	0.66	3.79 - 4.49
Usefulness of the in-class activities	4.79	0.43	4.57 - 5.00
Usefulness of the outside assignments	4.71	0.47	4.46 - 4.96
Value of time spent on course	4.50	0.52	4.23 - 4.77

Term: Fall 2017 Session: 1 Course: PHYS 332 001/00[redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	4.00	2.23	3.39 - 4.61
Amount learned	3.20	0.84	2.47 - 3.93
Difficulty level of the course	3.67	0.72	3.30 - 4.04
Overall instructor comparison	2.20	0.84	1.47 - 2.93
Overall rating of teaching effectiveness	2.60	0.89	1.82 - 3.38
Overall rating of the course	2.80	1.10	1.84 - 3.76
Students treated with respect	4.00	0.71	3.37 - 4.63
Usefulness of course materials	3.20	0.84	2.47 - 3.93
Usefulness of the in-class activities	2.80	1.10	1.84 - 3.76
Usefulness of the outside assignments	3.00	1.22	1.92 - 4.08
Value of time spent on course	3.20	0.84	2.47 - 3.93

Term: Fall 2017 Session: 1 Course: PHYS 371 001/002[redacted]A

Question Category	Mean	Std. Dev	95% Conf Int
-	4.52	2.14	4.15 - 4.89
Amount learned	4.36	0.67	3.97 - 4.75
Difficulty level of the course	4.06	0.72	3.81 - 4.31
Overall instructor comparison	4.36	0.92	3.81 - 4.91
Overall rating of teaching effectiveness	4.18	0.98	3.59 - 4.77
Overall rating of the course	4.09	0.94	3.54 - 4.64
Students treated with respect	4.64	0.67	4.25 - 5.00
Usefulness of course materials	4.10	0.74	3.65 - 4.55
Usefulness of the in-class activities	4.27	1.01	3.68 - 4.86
Usefulness of the outside assignments	4.27	1.19	3.56 - 4.98
Value of time spent on course	4.55	0.69	4.14 - 4.96

Difficulty level of the course	4.38	0.82	4.30 - 4.46
Overall instructor comparison	2.78	[redacted] 1.16	2.58[redacted].98
Overall rating of teaching effectiveness	3.28	1.13	3.10 - 3.46
Overall rating of the course	2.72	1.17	2.52 - 2.92
Students treated with respect	4.02	0.96	3.86 - 4.18
Usefulness of course materials	3.60	1.17	3.40 - 3.80
Usefulness of the in-class activities	3.69	1.18	3.49 - 3.89
Usefulness of the outside assignments	3.96	1.05	3.78 - 4.14
Value of time spent on course	3.81	1.07	3.63 - 3.99

Term: Fall 2017 Session: 1 Course: PHYS 140 001/002[redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	3.78	1.74	3.13 - 4.43
Amount learned	2.00	1.00	1.00 - 3.14
Difficulty level of the course	4.11	0.93	3.50 - 4.72
Overall instructor comparison	1.33	[redacted] 0.58	1.00[redacted]98
Overall rating of teaching effectiveness	1.67	0.58	1.02 - 2.32
Overall rating of the course	1.67	0.58	1.02 - 2.32
Students treated with respect	3.67	1.53	1.95 - 5.00
Usefulness of course materials	3.00	1.73	1.04 - 4.96
Usefulness of the in-class activities	1.33	0.58	1.00 - 1.98
Usefulness of the outside assignments	2.67	1.15	1.36 - 3.98
Value of time spent on course	1.67	0.58	1.02 - 2.32

Term: Fall 2017 Session: 1 Course: PHYS 405/505 00[redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	4.80	2.29	4.37 - 5.00
Amount learned	4.67	0.50	4.34 - 5.00
Difficulty level of the course	4.19	0.68	3.94 - 4.44
Overall instructor comparison	4.00	[redacted] 1.00	3.35[redacted]4.65
Overall rating of teaching effectiveness	4.56	0.73	4.09 - 5.00
Overall rating of the course	4.44	0.73	3.97 - 4.91
Students treated with respect	5.00	0.00	5.00 - 5.00
Usefulness of course materials	4.75	0.46	4.44 - 5.00
Usefulness of the in-class activities	4.44	1.01	3.77 - 5.00
Usefulness of the outside assignments	4.56	0.73	4.09 - 5.00
Value of time spent on course	4.56	0.53	4.21 - 4.91

Term: Fall 2017 Session: 1 Course: PHYS 440/540 00[redacted] J

Question Category	Mean	Std. Dev	95% Conf Int
-	4.66	1.86	4.21 - 5.00
Amount learned	4.17	0.75	3.56 - 4.78
Difficulty level of the course	4.00	0.59	3.73 - 4.27
Overall instructor comparison	3.67	[redacted] 0.52	3.26[redacted]4.08
Overall rating of teaching effectiveness	4.17	0.75	3.56 - 4.78
Overall rating of the course	4.00	0.63	3.49 - 4.51
Students treated with respect	5.00	0.00	5.00 - 5.00

Term: Fall 2017 Session: 1 Course: PHYS 426 001/002 [redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	3.90	2.23	3.37 - 4.43
Amount learned	3.00	1.10	2.12 - 3.88
Difficulty level of the course	3.44	0.51	3.20 - 3.68
Overall instructor comparison	2.33	1.21	1.37 - 3.29
Overall rating of teaching effectiveness	3.00	1.67	1.67 - 4.33
Overall rating of the course	2.83	1.17	1.89 - 3.77
Students treated with respect	4.33	0.82	3.68 - 4.98
Usefulness of course materials	[redacted].00	0.00	5.00 - [redacted].00
Usefulness of the in-class activities	3.00	1.67	1.67 - 4.33
Usefulness of the outside assignments	3.67	1.03	2.85 - 4.49
Value of time spent on course	3.83	1.60	2.56 - 5.00

Term: Fall 2017 Session: 1 Course: PHYS 472/572 00[redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	4.69	2.10	4.32 - 5.00
Amount learned	4.30	0.67	3.89 - 4.71
Difficulty level of the course	3.57	0.57	3.37 - 3.77
Overall instructor comparison	4.80	0.63	4.41 - 5.00
Overall rating of teaching effectiveness	4.90	0.32	4.70 - 5.00
Overall rating of the course	4.70	0.67	4.29 - 5.00
Students treated with respect	4.70	0.67	4.29 - 5.00
Usefulness of course materials	4.80	0.42	4.55 - [redacted].00
Usefulness of the in-class activities	4.60	0.52	4.29 - 4.91
Usefulness of the outside assignments	4.70	0.48	4.41 - 4.99
Value of time spent on course	4.60	0.52	4.29 - 4.91

Term: Fall 2017 Session: 1 Course: PHYS 240/241 001 [redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	3.82	1.72	3.74 - 3.90
Amount learned	3.21	1.09	3.03 - 3.39
Difficulty level of the course	4.14	0.84	4.06 - 4.22
Overall instructor comparison	2.58	1.18	2.40 - 2.76
Overall rating of teaching effectiveness	2.94	1.17	2.76 - 3.12
Overall rating of the course	2.62	1.12	2.44 - 2.80
Students treated with respect	4.23	0.85	4.09 - 4.37
Usefulness of course materials	3.[redacted]	1.21	3.25 - [redacted].65
Usefulness of the in-class activities	2.96	1.26	2.76 - 3.16
Usefulness of the outside assignments	3.22	1.21	3.02 - 3.42
Value of time spent on course	3.42	1.07	3.24 - 3.60

Term: Fall 2017 Session: 1 Course: PHYS 102 001/2/3 [redacted]

Question Category	Mean	Std. Dev	95% Conf Int
-	4.10	2.01	4.00 - 4.20
Amount learned	3.56	1.05	3.38 - 3.74

Usefulness of course materials	4.50	0.55	4.07 - 4.93
Usefulness of the in-class activities	4.33	0.52	3.92 - 4.74
Usefulness of the outside assignments	4.50	0.55	4.07 - 4.93
Value of time spent on course	4.50	0.84	3.83 - 5.00

(65% Response)

C APR Teaching Rubric

Rubric for Self-Assessing Departmental Teaching Quality in the APR Self-Study

Indicate the self-assessment rating with a brief rationale in the appropriate cell.			Criteria for Assessing Teaching Quality
Exemplary	Developing	Needs Development	
			Expectations for Teaching Quality: A department is EXEMPLARY for this criterion if it has established a set of expectations for high-quality teaching at all levels of the curriculum that are clearly conveyed to all instructors. Expectations are based upon effective teaching practices demonstrated to improve student learning outcomes. All instructors are held to these expectations to the extent that is appropriate to the classes they teach and the terms of their appointments.
			Support for Teaching Development: A department is EXEMPLARY for this criterion if it has in place standard processes for encouraging professional development towards high-quality teaching across the whole unit. These processes include the provision of clear information about and ready access to resources, inside and outside the department that can help all instructors develop the quality of their teaching. All these processes are aligned with the department's established expectations for teaching quality. Avenues for development may include, but need not be limited to, peer coaching, consultations with OIA, and support for attending workshops and conferences focused on enhancing the quality of teaching.
			Evaluation of Teaching: A department is EXEMPLARY for this criterion if it has an established and transparent process for evaluating teaching quality for all instructors. The evaluation criteria are tightly linked to the department's established set of expectations for teaching quality. The evaluation process includes, but is not limited to, student evaluations, peer evaluation of teaching, and instructor self- reflection. Evaluating teaching quality is a key part of annual reviews as well as promotion and tenure reviews.
			Applying Findings to Teaching Improvements: A department is EXEMPLARY for this criterion if it has an ongoing process that includes steps in which teaching evaluations are reviewed and incorporated into department plans for both programmatic and individual goals improvement. All steps of this application phase are linked to the department's established set of expectations for teaching quality.

D Faculty CV's

ELLIOTT C. CHEU
Professor of Physics
Department of Physics
University of Arizona
Tucson, AZ 85721
BIOGRAPHICAL SKETCH
echeu@email.arizona.edu

Education
B.S., Physics, Stanford University, 1986
Ph.D., Physics, Cornell University, 1991
"Measurement of the Hadronic Cross Section above the $\Upsilon(4S)$ and B^* Production"
Postdoctoral Training, Physics, University of Chicago, 1991-1996

Research and Professional Experience
Interim Dean, Honors College, University of Arizona, 2016-2017
University Distinguished Professor, University of Arizona, 2016-present
Associate Dean, College of Science, University of Arizona, 2008-present
Professor, University of Arizona, 2008-present
Associate Professor, University of Arizona, 2002-2008
Assistant Professor, University of Arizona, 1996-2002
Research Scientist, University of Chicago, 1994-1996
McCormick Fellow, University of Chicago, 1991-1994

Publications
1. "Search for pair and single production of new heavy quarks that decay to a *Z* boson and a third-generation quark in *pp* collisions at *sqrt(s)*=8 TeV with the ATLAS detector," G. Aad *et al.*, JHEP 11 (2014) 104.
2. "Search for supersymmetry in events with three leptons and missing transverse momentum in sqrt(s) = 7 TeV pp collisions with the ATLAS detector," G. Aad *et al*., Phys. Rev. Lett. 108 (2012) 261804.
3. "Spectroscopic needs for imaging dark energy experiments,"J. A. Newman *et al.*, Astropart. Phys., 63 (2014) 81.
4. "Precise Measurements of Direct CP Violation, CPT Symmetry, and Other Parameters in the Neutral Kaon System," E. Abouzaid et al., Phys Rev D83, (2011) 092001.
5. "Development of large size Micromegas detector for the upgrade of the ATLAS muon system," T. Alexopoulos *et al*., Nucl Instrum. Meth. A617 (2010) 161.
6. "The ATLAS muon Micromegas R&D project: Towards large-size chambers for the s-LHC," T. Alexopoulos *et al.*, JINST 4 (2009) P12015.
7. "Cathode strip chambers in ATLAS: Installation, commissioning and in situ performance," T. Argyropoulos *et al*., IEEE Trans. Nucl. Sci 56 (2009) 1568.
8. "Final Results from the KTeV Experiment on the Decay $K_L \to \pi^0\gamma\gamma$," E. Abouzaid *et al.*, Phys Rev D77 (2008) 112004.
9. "A Combined search for the standard model Higgs boson at $\sqrt{s}$ = 1.96-TeV," V.M. Abazov *et al.*, Phys. Lett. B663 (2008) 26.
10. "Search for $B_s \to \mu^+\mu^-$ at D0," V.M. Abazov *et al.*, Phys.Rev. D76 (2007) 092001.

Synergistic Activities
Reviewer for DOE and NSF

Collaborators and Co-editors
Member of ATLAS and DESC Collaborations
Nuno Castro, LIP-Minho, Portugal
Mark Cooke, Lawrence Berkeley Laboratory
David Kirkby, University of California, Irvine
Sam Schmidt, University of California, Davis

Graduate and Postdoctoral Advisors
Nari Mistry, Cornell University
Bruce Winstein, University of Chicago

Recent Graduate and Postdoctoral Advisees
Postdocs:
Prolay Mal, National Institute of Science Education and Research, India
Alexandra Abate, Dia&Co
Christina Delitzsch, University of Arizona

Graduate Students:
Jianbo Wang, Texas Instruments, Tucson, AZ
Caleb Lampen, Aerospace Corporation, El Segundo, CA
Matthew Leone, MITRE, Aberdeen, MD
You Zhou, University of Arizona
Lidens Cheng, University of Arizona
Billie Lubis, University of Arizona
Nick Canales, University of Arizona

BIOGRAPHICAL SKETCH: Alexander D. Cronin (updated Oct. 2015)

Professional Preparation	Stanford University	Physics	B.S.	1993
	University of Washington	Physics	Ph.D.	1999
	Massachusetts Institute of Technology	Physics Postdoc.		1999 – 2002

Appointments	Professor,	U. of Arizona, Department of Physics	2015 – present
	Associate Professor,	U. of Arizona, Department of Physics	2008 – 2015
	Joint Appointment,	U. of Arizona, Optical Sciences	2004 – present
	Assistant Professor,	U. of Arizona, Department of Physics	2002 – 2008

Five publications related to this proposal:

"Measurements of the Ground-State Polarizabilities of Cs, Rb, and K using Atom Interferometry," M.D. Gregoire, I. Hromada, W.F. Holmgren, R. Trubko, and A.D. Cronin, *arXiv preprint arXiv:1509.07091*, accepted for publication in *Physical Review A* (2015).

"De Broglie wave-front curvature induced by electric-field gradients and its effect on precision measurements with an atom interferometer," I. Hromada, R. Trubko, W.F. Holmgren, M.D. Gregoire, and A.D. Cronin." *Physical Review A*, **89**, 033612 (2014).

"Measurement of a Wavelength of Light for Which the Energy Shift for an Atom Vanishes," W.F. Holmgren, R. Trubko, I. Hromada, and A.D. Cronin. *Physical Review Letters*, **109**, 243004 (2012).

"Can atom–surface potential measurements test atomic structure models?," V.P. A. Lonij, C.E. Klauss, W.F. Holmgren, and A.D. Cronin, *J. Phys. Chem. A* **115**, 7134 (2011).

"Atom diffraction reveals the impact of core electrons on atom-surface potentials," V.P.A. Lonij, W. Holmgren, C. Klauss, A.D. Cronin , *Physical Review Letters*, **105**, 233202 (2010).

Five additional publications:

"Atom Interferometer Gyroscope with Spin-Dependent Phase Shifts Induced by Light near a Tune-Out Wavelength," R. Trubko, J. Greenberg, M.T. St Germaine, M.D. Gregoire, W.F. Holmgren, I. Hromada, and A.D. Cronin. *Phys. Rev. Lett.* **114**,140404 (2015).

"Absolute and ratio measurements of the polarizability of Na, K, and Rb with an atom interferometer," W.F. Holmgren, M.C. Revelle, V.P.A. Lonij, and A.D. Cronin, *Phys. Rev. A* 81, 053607 (2010).

"Observation of atom wave phase shifts induced by van der Waals atom-surface interactions," J.D. Perreault, T.A. Savas, A.D. Cronin, *Phys. Rev. Lett*. **95**, 133201 (2005).

"From single- to multiple-photon decoherence in an atom interferometer," D.A. Kokorowski, A.D. Cronin, T.D. Roberts, and D.E. Pritchard, *Phys. Rev. Lett*. **86**, 2191 (2001).

"Optics and interferometry with atoms and molecules," A.D. Cronin, J. Schmiedmayer, D.E. Pritchard, *Reviews of Modern Physics* **81**, 1501 (2009).

Awards and Honors

Faculty Fellow, Udall Center for Studies in Public Policy	2015 – 2016
Koffler Prize for Teaching, University of Arizona,	2009
Honors College Outstanding Professor Award, University of Arizona,	2009
Early Career Distinguished Teaching Award, U. of Arizona College of Science,	2008
Outstanding Undergraduate Teaching Award, U. of Arizona Dept. of Physics,	2005
NSF Graduate Research Fellowship,	1996 – 1999
ARCS Fellowship,	1994 – 1997

Synergistic Activities

Conference committee work: ICAP 2002 local organizing committee, DAMOP 2004 local organizing committee, DAMOP 2004 Public Lecture coordinator, CLEO/QELS 2007 sorting committee, ITAMP quantum reflection workshop co-organizer 2007, DAMOP 2008 Thesis Prize committee, DAMOP 2008 session chair, DAMOP 2009 Thesis Prize committee chair, IEEE PVSC 2012 sorting committee and manuscript reviewer, IEEE PVSC 2013 sub-Area Chair and manuscript reviewer, Frontiers of Matter Wave Optics 2014 scientific organizing committee.

University Committees: Optical Sciences faculty search 2005-2006, Arizona Research Institute for Solar Energy (AZRISE) advisory committee 2008-2012, College of Science Student Advising committee 2008-2009, Biosphere2 strategic plan committee 2009-2010, Biosphere 2 science advisory group 2012-2013, College of Engineering Energy Storage faculty search committee 2009-2010, Science Foundation Arizona graduate student summit co-organizer 2010, Koffler Prize committee 2011, Institute for the Environment WEES Grant selection committees 2012, 2013, 2014, Honors College Convocation Speaker 2012, Scientific exchange visiting committee to the country of Oman, 2013.

Department of Physics Committees: Colloquium committee 2002-2004, 2011-2012, CM faculty search committee 2003, 2004, Graduate Admissions committee 2004-2013, Building space committee 2004-2009, Ph.D. oral exam committees for over 50 students 2004-present, Physics Department Head search 2004-2005, Nuclear Physics faculty search 2004-2005, Experimental AMO/CM physics faculty search 2005-06, CM/AMO seminar co-organizer 2006-07, Undergraduate Physics Club advisor 2006-2012, Bickel-lab machine shop coordinator 2006-2010, New TA training 2006-2012, Graduate Student Advisor 2006-2009,Undergraduate Academic Advisor 2006-2013, Executive Committee 2006-2009, 2012-2013, Curriculum Committee 2008-2009, Physics Freshman Orientation co-coordinator 2008, Physics Undergraduate Mentors Program coordinator 2008-2009, Undergraduate Research Symposium MC and co-organizer 2008, Director of Undergraduate Studies 2008-2009, CAPE committee 2009-2010, Faculty Search Committee (CM/AMO Experiment) Chair2010-2011, Student Awards Committee 2010-2011, Faculty Awards Committee 2012-2013, Women in Physics club advisor 2013-2015.

Referee for Journals: Physical Review A, B, E, X, and Letters, European Journal of Physics D, Europhysics, Nature , Nature Physics, New Journal of Physics, Journal of Applied Physics, Journal of Physics B, Journal of Optics & Laser Technology Journal of Physical Chemistry, Nature Communications, Applied Physics Letters, Optics Express, Journal of Solar Energy.

Reviewer for funding agencies: National Science Foundation (NSF), Research Corporation, European Science Foundation (ESF), European Space Agency (ESA), Israeli Science Foundation (ISF), The Marsden fund (New Zeeland), NASA Planetary Instrument Definition and Design, Gordon and Betty Moor foundation, Canadian Science Foundation, Shell-NWO/FOM Computational Science Grants, Cooperative Grants Program of the U.S. Civilian Research and Development Foundation (CRDF), French Agence National pour la Recherche.

Collaborators

PhD Dissertation Advisor: E. Norval Fortson Postdoc Advisor: D.E. Pritchard

PhD Dissertation Students John D. Perreault, Ben McMorran, Vincent Lonij, William Holmgren, Ivan Hromada, Daniel Cormode, (current: Raisa Trubko, Antonio Lorenzo, Maxwell Gregoire)

MS Thesis students Greg Schwarz, Emily Kopp, Patricia Hidalgo-Gonzalez, Sophia Chen

BS. Thesis Students Cathy Klauss, Melissa Revelle, Victoria Adra Carr, Yancey Sechrest, Scott R. Waitukaitis, Adam DeBolt, Robert Wild, James Greenberg (current: Nathan Brooks)

Other Collaborators and Coauthors: Brian Anderson, Pierre Meystre, Joerg Schmiedmayer, Peter Toennies, Jacques Vigué, Henry I. Smith, Tim Savas, Joe Simmons, Bruce Doak, Raymond Kostuk, Govindasamy Tamizhmani, Sarah Kurtz, Mishkat Bhattacharya, Warren Beck, William Conant, George Maracas, Moe Momayez, Rong Pan, Roger Angel, Ardeth Barnhardt, Eric Betterton, Nathan Allen, Michael Tyler St. Germaine, Michael Leuthold, Steven Lepoutre, Heikel Jelassi, Matthias Bruchner, Dirk Jordan, Steve Pulver, Vijai Jayadevan, Jeff Rodriguez, Chang Ki Kim, Adria Brooks, Josh Fijal, Sean Orsburn, Daniella Della-Giustina, Kevin Koch, Charles Hasselbrinck, Spencer Olson, Matthew Squires, Bodil Holst, Gabriel Dutier

ABRIDGED CV — Prof. Keith R. Dienes

Education

Cornell University	Physics	Ph.D.	5/91
Cornell University	Physics	M.S.	1/89
Princeton University	Physics	A.B. with Honors	6/85

Major Professional Appointments

NSF	Program Director, HEP Theory	current
University of Arizona	Full Professor	8/09 – current
University of Arizona	Director of Graduate Studies, Physics	8/05 – 7/09
University of Arizona	Associate Professor	8/03 – 8/09
University of Arizona	Assistant Professor	8/99 – 8/03
CERN Theory Division	Postdoctoral Fellow	9/97 – 8/99
IAS, Princeton	Postdoctoral Fellow	8/94 – 8/97
McGill University	Postdoctoral Fellow	8/91 – 8/94
Cornell University	Graduate Research Asst.	8/87 – 8/91

Significant Publications (representing several of my dominant career research themes):

1. Dynamical Dark Matter and Non-Minimal Dark Sectors in Collider Physics, Astrophysics, and Cosmology: K.R. Dienes and B. Thomas, *Dynamical Dark Matter: I. Theoretical Overview*, *Phys. Rev.* **D85** (2012) 083523; *Dynamical Dark Matter: II. An Explicit Model*, *Phys. Rev.* **D85** (2012) 083524; K.R. Dienes, S. Su, and B. Thomas, *Distinguishing Dynamical Dark Matter at the LHC*, *Phys. Rev.* **D86** (2012) 054008; *Strategies for Probing Non-Minimal Dark Sectors at Colliders: The Interplay Between Cuts and Kinematic Distributions*, *Phys. Rev.* **D91** (2015) 054002; K.R. Dienes, J. Kumar, and B. Thomas, *Direct Detection of Dynamical Dark Matter*, *Phys. Rev.* **D86** (2012) 055016; *Dynamical Dark Matter and the Positron Excess in Light of AMS*, *Phys. Rev.* **D88** (2013) 103509; K.R. Dienes, J. Kumar, B. Thomas, and D. Yaylali, *A New Direction in Dark-Matter Complementarity: Dark-Matter Decay as a Complementary Probe of Multi-Component Dark Sectors*, *Phys. Rev. Lett.* **114** (2015) 051301; *Off-Diagonal Dark-Matter Phenomenology: Exploring Enhanced Complementarity Relations in Non-Minimal Dark Sectors*, *Phys. Rev.* **D96** (2017) 115009; K.R. Dienes, J. Kost, and B. Thomas, *A Tale of Two Timescales: Mixing, Mass Generation, and Phase Transitions in the Early Universe*, *Phys. Rev.* **D93** (2016) 043540; *Kaluza-Klein Towers in the Early Universe: Phase Transitions, Relic Abundances, and their Applications to Axion Cosmology*, *Phys. Rev.* **D95** (2017) 123539; K.R. Dienes, F. Huang, S. Su, and B. Thomas, *Dynamical Dark Matter from Strongly-Coupled Dark Sectors*, *Phys. Rev.* **D95** (2017) 043526; K.R. Dienes, J. Fennick, J. Kumar, and B. Thomas, *Dynamical Dark Matter from Thermal Freeze-Out*, `arXiv:1712.09919` [submitted to PRD]; and many others...

2. Extra spacetime dimensions and brane-world scenarios: K.R. Dienes, E. Dudas, and T. Gherghetta, *Extra Spacetime Dimensions and Unification*, *Phys. Lett.* **B436**, 55 (1998); *Grand Unification at Intermediate Mass Scales through Extra Dimensions*, *Nucl. Phys.* **B537**, 47 (1999); K.R. Dienes, *Shape versus Volume: Making Large Flat Extra Dimensions Invisible*, *Phys. Rev. Lett.* **88** (2002) 011601; K.R. Dienes, E. Dudas, and T. Gherghetta, *GUT Precursors and Non-Trivial Fixed Points in Higher-Dimensional Gauge Theories*, *Phys. Rev. Lett.* **91** (2003) 061601; S. Bauman and K.R. Dienes, *New*

Regulators for Quantum Field Theories with Compactified Extra Dimensions, Parts I and II, *Phys. Rev.* **D77** (2008) 125005 and 125006. Many other related papers focus on axion physics, cosmological phase transitions, radius stabilization, string winding modes, radiative corrections in KK theories, *etc.*

3. *Non-supersymmetric alternatives in field theory and string theory / Alternative approaches to the hierarchy problem:* K.R. Dienes, *Modular Invariance, Finiteness, and Misaligned Supersymmetry: New Constraints on the Numbers of Physical String States*, *Nucl. Phys.* **B429**, 533 (1994); K.R. Dienes, M. Moshe, and R.C. Myers, *String Theory, Misaligned Supersymmetry, and the Supertrace Constraints*, *Phys. Rev. Lett.* **74**, 4767 (1995); J.D. Blum and K.R. Dienes, *Strong/Weak Coupling Duality Relations for Non-Supersymmetric String Theories*, *Nucl. Phys.* **B516**, 83 (1998); K.R. Dienes, *Solving the Hierarchy Problem without Supersymmetry or Extra Dimensions: An Alternative Approach*, *Nucl. Phys.* **B611**, 146 (2001); S.A. Abel, K.R. Dienes, and E. Mavroudi, *Towards a Non-Supersymmetric String Phenomenology*, *Phys. Rev.* **D91** (2015) 126014; *GUT Precursors and Entwined SUSY: The Phenomenology of Stable Non-Supersymmetric Strings*, `arXiv:1712.06894` [submitted to PRD].

4. *New approaches for neutrino masses and mixings:* K.R. Dienes, E. Dudas, and T. Gherghetta, *Light Neutrinos without Heavy Mass Scales: A Higher-Dimensional Seesaw Mechanism*, *Nucl. Phys.* **B557**, 25 (1999); K.R. Dienes and I. Sarcevic, *Neutrino Flavor Oscillations without Flavor Mixing Angles*, *Phys. Lett.* **B500**, 133 (2001); K.R. Dienes and S. Hossenfelder, *A Hybrid Model of Neutrino Masses and Oscillations: Bulk Neutrinos in the Split-Fermion Scenario*, *Phys. Rev.* **D74**, 065013 (2006).

5. *High-scale string phenomenology and string unification:* K.R. Dienes and A.E. Faraggi, *Making Ends Meet: String Unification and Low-Energy Data*, *Phys. Rev. Lett.* **75**, 2646 (1995); *Gauge Coupling Unification in Realistic Free-Fermionic String Models*, *Nucl. Phys.* **B457**, 409 (1995); K.R. Dienes and J. March-Russell, *Realizing Higher-Level Gauge Symmetries in String Theory: New Embeddings for String GUTs*, *Nucl. Phys.* **B479**, 113 (1996). K.R. Dienes, *New Constraints on SO(10) Model-Building from String Theory*, *Nucl. Phys.* **B488**, 141 (1997). Other papers have focused on extra $U(1)$'s, unusual Standard-Model embeddings, *etc.* Also authored an extensive review article: K.R. Dienes, *String Theory and the Path to Unification: A Review of Recent Developments*, *Physics Reports* **287**, 447 (1997).

6. *String model-building/string landscape:* K.R. Dienes, *Statistics on the Heterotic Landscape: Gauge Groups and Cosmological Constants of Four-Dimensional Heterotic Strings*, *Phys. Rev.* **D73**, 106010 (2006); K.R. Dienes, M. Lennek, D. Sénéchal, and V. Wasnik, *Supersymmetry versus Gauge Symmetry on the Heterotic Landscape*, *Phys. Rev.* **D75** (2007) 126005; *Is SUSY Natural?*, *New J. Phys.* **10** (2008) 085003. Also wrote an invited review article: K.R. Dienes, *Probing the String Landscape: Implications, Applications, and Altercations*, *IJMP* **A30** (2015) 1530017 and *Adv. Ser. Direct. High Energy Phys.* **22** (2015) 81-115.

Selected Honors and Service/Outreach Activities

- Currently serving as Program Director for Theoretical High-Energy Physics and Cosmology at the US National Science Foundation, where I oversee all aspects of NSF-sponsored financial support for theoretical high-energy physics and cosmology research across the United States. This includes serving as the voice of theoretical particle physics and cosmology within NSF and in various interagency and academy settings (including HEPAP and AAAC advisory committees). It also includes interacting with the research community regularly on all matters relating to research support, including developing a strategic vision for the future as well as addressing periodic research and funding challenges. I also oversee the "broader impacts" of this NSF-sponsored research, including the education and training of young researchers, developing new funding streams, and enhancing the level of public outreach, education, and dissemination of research results across the US. (**Note:** *While holding this position, I maintain all of my usual research activity with my postdocs and graduate students in Arizona and remain funded through Arizona's DOE group grant.*)

- Nominated and elected as *Fellow of the American Physical Society*, Nov. 2010, through the Division of Particles and Fields. Citation reads: *"For his seminal contributions to our understanding of grand unification, and for his work studying the diverse phenomenological implications of string theory and extra spacetime dimensions".*
- Won University-wide *2008 Outstanding Administrator of the Year* for my work as the Director of Graduate Studies for the Department of Physics; College-wide *Early-Career Teaching Award* (September 2004); University-wide *Graduate Advisor of the Year Award* (2001); Department *Excellence in Graduate Physics Teaching Award* (2002).
- Invited Lecturer at TASI Summer Schools in 1998, 2001, 2002, 2006, other schools...
- July 2004 – October 2008: Elected to serve as **Chair of the Four Corners Section of the American Physical Society** (Arizona, Colorado, New Mexico, Utah). Worked to increase student participation, mentoring, and research opportunities; to develop connections with physics institutions in neighboring regions; and to broaden the ethnic/cultural diversity of the next generation of physicists in the Southwest.
- Served as the **Head Organizer for the SUSY 2003 Conference**, held at the University of Arizona, June 2003. Responsible for all aspects of this six-day conference, which attracted over 200 participants with over 150 plenary and parallel talks. Also served as Head Organizer for the *String Vacuum Project Kickoff Meeting*, April 2008.
- More recently, served as co-Organizer of
  - **Rapid-Response Workshop "Probing Non-Minimal Dark Sectors"**, held at PITT-PACC, University of Pittsburgh, June 2014. PITT-PACC workshops promote interdisciplinary studies in particle physics, astrophysics, and cosmology.
  - **"HenryFest: Tying Particles and Strings to the Cosmos"**, held at Cornell University, October 2017. Three-day workshop with 52 participants and 27 talks on physics topics stretching from QCD, B-physics, and collider physics to string theory, string phenomenology, and string cosmology.
- *Public Outreach*: Numerous articles in popular science magazines, several TV and radio interviews (including on NPR's "Talk of the Nation: Science Friday"). Most recently (January 2017), I delivered a public evening lecture **"Rethinking the Rules of Reality"** in a large campus performance hall holding 2600 people, with 1000 more in various overflow rooms across campus and simultaneously live-streamed on the internet. This lecture generated considerable publicity online and in Arizona, including radio interviews and newspaper articles. *YouTube videos of this lecture have had 20,000 viewings within just the first year.*

Sean Fleming
University of Arizona

Education

NORTHWESTERN UNIVERSITY — Evanston, IL
Ph.D.: Physics.

GEORGETOWN UNIVERSITY — Washington, D.C.
B.Sc.: Physics

Employers

UNIVERSITY OF ARIZONA — Tucson, AZ
Professor, 2016–Date.
Associate Professor, 2011 – 2016.
Assistant Professor, 2005–2011

UNIVERSITY OF CALIFORNIA SAN DIEGO — La Jolla, CA
Research Associate, 2004 – 2005.

CARNEGIE MELLON UNIVERSITY — Pittsburgh, PA
Research Associate, 2000 – 2004. H

UNIVERSITY OF TORONTO — Toronto, Canada
Research Associate, 1997 – 2000.

UNIVERSITY OF WISCONSIN — Madison, WI
Research Associate, 1995 – 1997.

Awards

DOE grant, 2014–Date. Principal Investigator DE-FG02-04ER41338.
DOE grant, 2011–2014. Co-Principal Investigator DE-FG02-04ER41338.
DOE grant, 2009–2011. Principal Investigator DE-FG02-06ER41449.
Outstanding Junior Investigator Award, 2006–2009. DOE grant DE-FG02-06ER41449.

Graduate Students Supervised

1. Justin Lieffers, Joined Group Spring 2018, Research Topic: Transverse Momentum Dependent Distributions in QCD.
2. Jaber Balalhabashi, Joined Group Spring 2016, Research Topic: Singular potentials in Atomic and Nuclear Physics.
3. Ou Zhang, Joined group Fall 2011, Research Topic: Effective Field Theories of Strong Interactions (Graduated December 2016).
4. Michael Fickinger, Joined group Fall 2006, Research Topic: precision QCD, collider phenomenology (Graduated May 2012).
5. Emanuele Mereghetti, Joined group Winter 2006, Research Topic: nuclear form factors (Graduated May 2011).

Supervised Continued

6. Delphine Perrodin, Joined group Fall 2007, Research Topic: gravitational radiation from in-spiraling black holes. (Graduated May 2009).

Service & Outreach

1. *Director of Graduate Studies:* Fall 2016–Date.
2. *Grad Admissions:* 2016–Date.
3. *Grad Recruitment:* 2016–Date.
4. *Teaching Evaluation/Innovation:* 2015–Date.
5. *Grad Curriculum:* 2015–Date.
6. *Space:* 2013-2014.
7. *CAPE:* 2013–2014.
8. *Faculty & StaffAwards :* 2013–2014.
9. *Student & Staff Awards:* 2010–2012.
10. *Examinations:* 2008–2010, 2013–2014, 2015–2016.
11. *Grad Advisor:* 2007–Date.
12. *Undergrad Service Courses:* 2006 – 2010, 2013–2014.
13. *Colloquium:* 2006–2008.
14. *Physics Phun Night volunteer:* Fall 2005, Fall 2006, Fall 2007.

Courses Taught

1. *Calculus based Introduction to Mechanics:* Fall 2015.
2. *Introduction to Scientific Computing:* Fall 2014, Spring 2016.
3. *Electricity and Magnetism II:* Fall 2013, Fall 2015.
4. *Calculus based Introduction to Electricity & Magnetism:* Spring 2012, Fall 2017.
5. *Theoretical Classical Mechanics:* Fall 2010.
6. *Mathematical Methods for Physicists:* Spring 2006 & Spring 2012.
7. *Graduate Quantum Mechanics:* Fall & Spring 2006 – Spring 2009.
8. *Introductory Algebra based Physics:* Fall 2008, Spring 2013, Spring 2014.
9. *Quantum Field Theory:* Spring 2010, Spring 2017.

Recent Articles

1. S. Fleming and O. Z. Labun, Rapidity regulators in the semi-inclusive deep inelastic scat-tering and Drell-Yan processes, *Phys. Rev. D* **95** (2017) 114020.
2. M. Fickinger, S. Fleming, C. Kim, E. Mereghetti, Effective field theory approach to heavy quark fragmentation, *JHEP* **1611** (2016) 095.
3. S. Fleming and O. Z. Labun, Rapidity Divergences and Deep Inelastic Scattering in the Endpoint Region, *Phys. Rev. D* **91** (2015) 094011.
4. S. Fleming, The role of Glauber exchange in soft collinear effective theory and the Balitsky-Fadin-Kuraev-Lipatov Equation, *Phys. Lett. B* **735** (2014) 266.

Samuel E. Gralla

Assistant Professor of Physics
Core faculty, Theoretical Astrophysics Program
The University of Arizona
sgralla@email.arizona.edu

Research Interests

(Astro)physics of strong gravitational and electromagnetic fields.
Theory of motion and gravitational radiation in general relativity.
Extremal black holes: theoretical properties and observational signatures.
Compact object astrophysics: black holes, neutron stars, pulsars, binaries.
Plasma in strong magnetic fields, quantum electrodynamical corrections.

Education and Professional Experience

Assistant Professor of Physics, University of Arizona (2015-)

Postdoctoral Fellow, Harvard University (2014-15)

Einstein Postdoctoral Fellow, University of Maryland (2011-14)

Ph.D., Physics, University of Chicago [advisor: Robert Wald] (2011)

B.S., Mathematics & Physics, Yale University (2005)

Prizes and Fellowships

NSF CAREER Award (2018)

NASA Einstein Fellowship (2011)

Sugarman Award for Excellence in Graduate Research, University of Chicago (2011)

Bloomenthal Fellowship (University of Chicago), awarded to the best graduate student in theoretical physics with advanced residency status (2010-2011)

Student speaking awards:
- Hartle Award, 19th International Meeting on General Relativity and Gravitation (2010)
- Blue Apple Award, Midwest Relativity Meeting (2009)
- Blue Apple Award, Midwest Relativity Meeting (2008)

NSF Graduate Research Fellowship (2005)

Deforest Pioneers Prize (Yale University), awarded to a senior physics major for distinguished creative achievement in physics (2005)

Service

Referee for: Astrophysical Journal, Cambridge University Press, Classical and Quantum Gravity, Entropy, Journal of Cosmology and Astroparticle Physics, Foundations of Physics, General Relativity and Gravitation, Journal of High Energy Physics, Monthly Notices of the Royal Astronomical Society, Modern Physics Letters A, Nature, Nature Astronomy, Physics Letters B, Physical Review D, Physical Review Letters, Proceedings of the Royal Society A

NSF external reviewer (2016, 2017) and panelist (year redacted)
Abstract Sorter, APS April Meeting 2013
Session Chair, APS April Meetings 2012, 2014, 2015
Scientific Organizing Committee, 15th Capra Meeting on Radiation Reaction (2012)

References

Prof. Roger Blandford
Stanford University
rdb3@stanford.edu

Prof. Scott Hughes
Massachusetts Institute of Technology
sahughes@mit.edu

Prof. Ted Jacobson
University of Maryland
jacobson@umd.edu

Prof. Andrew Strominger
Harvard University
strominger@physics.harvard.edu

Prof. Robert Wald
University of Chicago
rmwa@uchicago.edu

Kenneth A. Johns

Department of Physics, University of Arizona

Professional Preparation

B.A.	Physics	Rice University	1981
M.A.	Physics	Rice University	1983
Ph.D.	Physics	Rice University	1986
Postdoc	Physics	University of Minnesota	1986-1989

Appointments

2009-Present	Associate Head, Physics Department, University of Arizona
2000-Present	Professor, Physics Department, University of Arizona
1994-2000	Associate Professor, Physics Department, University of Arizona
1996-1998	Guest Scientist, Fermilab
1989-1994	Assistant Professor, Physics Department, University of Arizona
1986-1989	Research Associate, Physics Department, University of Minnesota

Products

1. *"A Search for $t\bar{t}$ Resonances Using Lepton plus Jets Events in Proton-Proton Collisions $\sqrt{s}$ =8 TeV with the ATLAS Detector",* ATLAS Collaboration, JHEP **08**, 148 (2015).
2. *"Observation of a New Particle in the Search for the Standard Model Higgs Boson with the ATLAS Detector at the LHC"*, ATLAS Collaboration, Phys. Lett. B **716** (2012) 1.
3. *"Upgraded Readout Electronics for the ATLAS Liquid Argon Calorimeters at the High Luminosity LHC"*, J. Phys. Conf. Ser. **404**, 012061 (2012).
4. *"Development of Large Size Micromegas Detectors for the Upgrade of the ATLAS Muon System",* T. Alexopoulos *et al*., Nucl.Instrum.Meth. A **617**, 161 (2010).
5. *"Cathode Strip Chambers in ATLAS: Installation, Commissioning and In-Situ Performance"*, IEEE Trans. Nucl. Sci. **56**, 1568 (2009).

Synergistic Activities

1. US ATLAS L3 Manager of the Micromegas Front End Card Project – 2014 – present
2. Head of the L1 Calorimeter-Track Trigger Project for the D∅ experiment, 2002 - 2007
3. Head of the L1 Muon Trigger Project for the D∅ experiment, 1995 - 2007
4. Co-head of the Muon Detector Upgrade Project for the D∅ experiment, 1996 – 1999
5. Member of the UA AAU Project to transform undergraduate STEM education 2013-2017

Collaborators:

I am a member of the ATLAS collaboration at CERN

Graduate Advisors and Postdoc Sponsors:

Jay Roberts, Rice University
Ken Heller, University of Minnesota
Marvin Marshak, University of Minnesota

Thesis Advisor and Postgraduate Scholar Sponsor:

Students Susan Burke, Hannah Carson (MS), Kevin Davis, Dave Fein, Bryan Gmyrek, Eric James, Sarah Jones, Finn O'Grady, Xiaowen Lei, Rachel Lindley (current), Rob McCroskey, Ajay Narayanan, Alex Smith, Jeff Temple, Jason Veatch, Dave Vititoe, Hao Zhou (current)
Research Associates Stefan Anderson, Simon Berlendis (current), Joan Guida, Venkat Kaushik, Leigh Markosky, Freedy Nang, Rushika Nayyar, Noah Wallace

Total Number of Graduate Students Sponsored and Postdoc Scholars Advised: 22

Honors and Awards

NSF Presidential Young Investigator, 1991-1995

Mohammed Hassan

Physics Department, University of Arizona
1118 E 4th Street, PO Box 210081,
Tucson, AZ. 85721-0081

***Office*: +1-520-626-1435**
***Cell*: +1-626-375-1387**
***e-mail*: mohammedhassan@email.arizona.edu**
***website:* www.hassan.lab.arizona.edu**

Professional History

- **Assistant professor of Physics** (8/2017-present)
  University of Arizona Physics Department
- **Postdoctoral Scholar** (9/2013-8/2017)
  California Institute of Technology, U.S.A.
  Physical Biology Center for Ultrafast Science and Technology (UST)
  Department of Chemistry & Chemical Engineering.
  Faculty Mentor: **Prof. Ahmed Zewail**
- **Postdoctoral Scholar** (2/2013-9/2013)
  Max-Planck institute of Quantum Optics (MPQ), Munich, Germany
  Faculty Mentor: **Prof. Dr. Ferenc Krausz and Dr. Eleftherios Goulielmakis**

Education

- **Ph.D. in Physics** (7/2009-3/2013)
  Physics Department, Ludwig-Maximillian University of Munich (LMU), Germany
  Max-Planck institute of Quantum Optics (MPQ), Munich, Germany
  Ph.D. advisor: **Prof. Dr. Ferenc Krausz and Dr. Eleftherios Goulielmakis**
  Thesis Topic: "Synthesis and control of attosecond light transients".
- **M.Sc. and Diploma in Laser Interactions with Matter (ranking #1)** (9/2004-6/2009)
  National Institute of Laser Enhanced Science, Cairo University, Egypt.
  Thesis Topic: "*Cancer treatment with naturally synthesized gold nanoparticles*".
- **B.Sc. in Chemistry (ranking top 5%)** (9/1999-9/2013)
  Faculty of Science, Cairo University, Egypt.

Honors and Awards

- The shortest pulse of visible light (Guinness World Records -2016)
- International Max-Planck Research School fellowship of Advanced Photon Sciences (IMPRS-APS), Germany. (2009-2012)
- Maiman Student Paper Competition semi-finalist. (2012)
- Egyptian Scientific Research Academy Master Fellowship for outstanding Graduate student in Science (ASRT-NILES), Egypt. (2004-2007).
- Award of Excellence for Outstanding Undergraduate Students in Science. (2003)

Professional Community Service

- Faculty mentor in the Arizona's Science, Engineering, and Math Scholars (ASEMS) program provides services to support minority students who are underrepresented in STEM.
- Represent the Optical Society of America (OSA) and National Photonics Initiative (NPI) in Congressional Visits Day (CVD)- Washington, DC on (25- 26) April 2017
- Member in the discussion panel of "Arab Knowledge Index", United Nations Development Programme.
- Member of "Young Professionals Program" in Optical Society of America (OSA).
- Executive member in Ultrafast Optical Phenomena (OU)
- Peer reviewer for the following journals: Nature Photonics, Nature communications, Optics Express, Journal of the Optical Society of America A, and Journal of Nanophotonics.

Teaching Experience

- Instructor, U of A, Physics (Phy161H, Phy 382, and Phy 381)

- Instructor, Caltech, Chemistry-Ch101 (Spring semester-2017)
- Teaching Assistant, British University in Egypt (BUE). (2007- 2009).

Refereed Publications

1. **M. Th. Hassan**, *Attomicroscopy: from femtosecond to attosecond electron microscopy*. ***J. Phys. B: At. Mol. Opt. Phys.*** 51, 032005, (2018).
2. **M. Th. Hassan***, J. S. Baskin, B. Laio, and A. H. Zewail, *High-temporal-resolution electron microscopy for imaging ultrafast electron dynamics*, ***Nature Photonics*** 11, 425–430 (2017).
   **corresponding author contribution*
   - **News and Views**
     Attosecond photonics: Imaging ultrafast electron dynamics (Nature Photonics).
3. X. Fu, B. Chen, J. Tang, **M. Th. Hassan**, A. H. Zewail, *Imaging rotational dynamics of nanoparticles in liquid by 4D electron microscopy*, ***Science***, 2017. **355** (6324): p. 494-498.
   - **News and Views**
     Laser-driven nanoparticle motion in liquids (Science)
4. **M. Th. Hassan**, T.T. Luu, A. Moulet, O. Razskazovskaya,P. Zhokhov, M. Garg, N. Karpowicz, A. M. Zheltikov,V. Pervak, F. Krausz and E. Goulielmakis, *Optical attosecond pulses and tracing the nonlinear response of bound electrons*, ***Nature*** 530, 66-70 (2016).
   - **News and Views**
     Optical physics: Ultrashort light pulses shake atoms (Nature)
     Shortest ever pulse of visible light spots photons fleeing atoms (New Scientist)
     Sluggish electrons caught in action (ScienceDaily)
     Superfast light pulses able to measure response time of electrons to light (Phys.org)
     Fastest Light Pulses Show Electrons Are Sluggish (IEEE spectrum)
     Sluggish electrons caught in action (ChemEurop).
5. **M. Th. Hassan**, H. Liu, J. S. Baskin, and A. H. Zewail, *Photon gating in four-dimensional ultrafast electron microscopy,* Proceedings of the National Academy of Sciences of the United States of America (**PNAS**) **, 112,** 12944-12949, (2015).
6. T. T. Luu, M. Garg, S. Y. Kruchinin, A. Moulet, **M. T. Hassan**, and E. Goulielmakis, *Extreme ultraviolet high-harmonic spectroscopy of solids*, ***Nature*** 521, 498 (2015).
7. Wirth, **M. Th. Hassan**, I. Grguraš, J. Gagnon, A. Moulet, T.T. Luu, S. Pabst, R. Santra, Z. Alahmed, A.M. Azzeer, V.S. Yakovlev, V. Pervak, F. Krausz and E. Goulielmakis, *Synthesized Light Transients*, ***Science*** 334, 195, (2011).
8. **M. Th. Hassan**, A. Wirth, I. Grguraš, A. Moulet, T.T. Luu, J. Gagnon, V. Pervak and E. Goulielmakis, "Invited Article": *Attosecond Photonics: Synthesis and Control of Light Transients*, ***Rev. Sci. Instrum***., 83 (2012) .
9. O. Razskazovskaya, **M. Th. Hassan**, T.T. Luu, E. Goulielmakis1 and V. Pervak, *Efficient broadband highly dispersive HfO2/SiO2 multilayer mirror for pulse compression in near UV*, ***Optics Express***, 24(12):13628-13633

Invited Talks

1. Attomicroscopy: Towards imaging the electron motion in real-time, UFO XI, October 2017, WY, USA.
2. Attomicroscopy: Towards imaging the electron motion by 4D Electron Microscopy, Femto13, August 2017, Cancun, Mexico.
3. Catching Electrons in the Act: Electron Motion Control and Imaging, Physics Department at the University of California Riverside (UCR), April 2017, Riverside, CA, USA.
4. Electron Motion Control and Imaging, Physics Department at the Michigan State University (MSU), February 2017, East Lansing, MI, USA.
5. Optical attosecond pulses: Tracing the nonlinear delay response of bound electrons in matter, UP 2016, July 2016, Santa Fe, New Mexico, USA.

CURRICULUM VITAE

Andrei G. Lebed

Department of Physics, _University of Arizona_, Tucson, AZ 85721
(520) 626-1031 = voice, e-mail: lebed@physics.arizona.edu, (520) 621-4721 = fax

Education

Doctor of Sciences: Full Professor's Degree in Physics and Mathematics, Landau Institute for Theoretical Physics, Moscow, Russia, 2000;
Ph.D. in Physics: Landau Institute for Theoretical Physics, Moscow, Russia, 1985;
M.S. Degree in Physics: Moscow Institute of Physics and Technology, Moscow, 1982.

Professional Appointments

Full Professor: Department of Physics, University of Arizona, 2010–present;
Associate Professor: Department of Physics, University of Arizona, 2004–2010;
Research Professor: Department of Physics, Boston College, 2002–2004;
Full Professor: Landau Institute for Theoretical Physics, 2000-2008;
Visiting Full Professor: Kyoto University (Kyoto, Japan), 2000-2001;
Associate Professor: Okayama University (Okayama, Japan), 1998-2000;
Associate Professor: Osaka Prefecture University (Osaka, Japan), 1997-1998;
Associate Professor: Tohoku University (Sendai, Japan), 1995-1997;
Visiting Scientist: Natl. High Magnetic Field Lab. (Tallahassee), 1993-1995;
Scientist: L.D. Landau Institute for Theoretical Physics (Moscow), 1990–2000;
Post-doctoral fellow: Brookhaven National Laboratory (Upton, USA), 1989;
Younger Scientist: Landau Institute for Theoretical Physics, 1985–1990.

Five Most Cited Publications

1. A.G. Lebed and K Yamaji, *Restoration of Superconductivity in a High Parallel Magnetic Field in Quasi-Two-Dimensional Compounds*, Physical Review Letters, vol. 80, p. 2697 (1998);
2. A.G. Lebed and P. Bak, *Theory of unusual anisotropy of magnetoresistance in organic superconductors*, Physical Review Letters, vol. 63, p. 1315 (1989);
3. A.G. Lebed, *Anisotropy of an instability for a spin-density-wave induced by a magnetic field in Q1D conductors*, JETP Letters, vol. 43, p. 174 (1986);
4. A.G. Lebed, Reversible Nature of the Orbital Mechanism for the Suppression of Superconductivity, JETP Letters, vol. 44, p. 114 (1986);
5. L.P. Gor'kov and A.G.Lebed, *On the stability of the quasi-one-dimensional metallic phase in magnetic fields against the spin-density-wave formation*, Journal de Physique (Paris) Letters, vol. 45, p. L-433 (1984).

Honors and Awards

2014: Fellow of the American Physical Society;
2001: 1-st Prize at *the Landau Institute* scientific competition;
1990: Lenin Komsomol Prize (the *major USSR Government prize* for scientists younger than 34);
1989: 2-nd Prize at the Academy of Sciences of the USSR competition for scientists younger than 34;
1988: 2-nd Prize at *the Landau Institute* scientific competition.

Synergetic Activities:

1) Creation of a course of lectures "Conventional and Unconventional Superconductivity" (Boston College, University of Arizona);
2) Creation of a course of lectures "Green Functions Methods in Many-body Theory" (University of Arizona);
3) Sole editor of a book "The Physics of Organic Superconductors and Conductors" (Springer, Berlin, 2008) (752 pages, 343 figures), devoted to 25th anniversary of organic superconductivity;
4) Participation in International Advisory Committees of more than 10 major international conferences;
5) Supervision of a Hispanic undergraduate student Mario Aletti (University of Arizona).

Most Recent Grants:

2011-2015: NSF individual grant "Organic Conductors and Superconductors in High Magnetic Fields" ($270,000).
2007-2011: NSF individual grant "Magnetic Properties of Organic Conductors and Superconductors" ($260,000).

Advisors:

1) M.S. Degree's and Ph.D. advisor - Professor Lev P. Gor'kov, Landau Institute for Theoretical Physics, Moscow, Russia, 1980-1985 (currently at the National High Magnetic Field Laboratory, Florida State University, Tallahassee, USA); 2) Post-doctoral advisor - Prof. Per Bak, Brookhaven National Laboratory, USA (deceased).

Supervision:

2015: Dr. Otar Sepper received his Ph.D under my supervision (University of Arizona).
2010: Dr. Si Wu received his Ph.D. under my supervision (University of Arizona).
Also, in the past, I was Ph.D. advisor and co-advisor of the following graduate students: Dr. Omjyoti Dutta (University of Arizona), Dr. T. Hayashi (Okayama University, Japan), Dr. K. Shankar (Boston College), Dr. J.I. Oh (Boston College), and Dr. Heon-Ick Ha (Boston College).

Brian LeRoy

Associate Professor, Physics Department, University of Arizona, P.O. Box 210081, Tucson, AZ 85721-0081; (Phone) 520-626-4726; (E-mail) leroy@physics.arizona.edu

Professional Preparation

University of Michigan	B.S.	Physics (Highest Honors), Math (High Honors)	1998
Harvard University	A.M.	Physics	2001
Harvard University	Ph.D.	Physics	2003

Appointments

Associate Professor, University of Arizona, Physics Department	2012-
Assistant Professor, University of Arizona, Physics Department	2006-2012
Post-doctoral Researcher, Delft University of Technology	2003-2006

Publications

Five most closely related

1. Tunable moire bands and strong correlations in small-twist-angle bilayer graphene
   K. Kim, A. DaSilva, S. Huang, B. Fallahazad, S. Larentis, T. Taniguchi, K. Watanabe, **B.J. LeRoy**, A.H. MacDonald, and E. Tutuc, *PNAS* **114**, 3364-3369 (2017).

2. "Pressure-induced commensurate stacking of graphene on boron nitride"
   M. Yankowitz, K. Watanabe, T. Taniguchi, P. San-Jose, **B.J. LeRoy**, *Nature Communications* **7**, 13168 (2016).

3. "van der Waals heterostructures with high accuracy rotational alignment"
   K. Kim, M. Yankowitz, B. Fallahazad, S. Kang, H.C.P. Movva, S. Huang, S. Larentis, C.M. Corbet, T. Taniguchi, K. Watanabe, S.K. Banerjee, **B.J. LeRoy**, E. Tutuc, *Nano Letters* **16**, 1989-1995 (2016).

4. "Local spectroscopic characterization of spin and layer polarization in WSe_2"
   M. Yankowitz, D. McKenzie, **B.J. LeRoy**, *Physical Review Letters* **115**, 136803 (2015). (Selected as Editor's Suggestion)

5. "Intrinsic disorder in graphene on transition metal dichalcogenide heterostructures"
   M. Yankowitz, S. Larentis, K. Kim, J. Xue, D. McKenzie, S. Huang, M. Paggen, M.N. Ali, R.J. Cava, E. Tutuc, **B.J. LeRoy**, *Nano Letters* **15**, 1925-1929 (2015).

Five other significant publications

6. "Electric field control of soliton motion and stacking in trilayer graphene"
   M. Yankowitz, J. Wang, A. G. Birdwell, Y. Chen, K. Watanabe, T. Taniguchi, P. Jacquid, P. San-Jose, P. Jarillo-Herrero, **B.J. LeRoy**, *Nature Materials* **13**, 786 (2014).

7. "Massive Dirac fermions and Hofstadter butterfly in a van der Waals heterostructure" B. Hunt, J.D. Sanchez-Yamagishi, A.F. Young, M. Yankowitz, **B.J. LeRoy**, K. Watanabe, T. Taniguchi, P. Moon, M. Koshino, P. Jarillo-Herrero, R.C. Ashoori, *Science* **340**, 1427-1430 (2013).

8. "Emergence of superlattice Dirac points in graphene on hexagonal boron nitride" M. Yankowitz, J. Xue, D. Cormode, J. Sanchez-Yamagishi, K. Watanabe, T. Taniguchi, P. Jarillo-Herrero, P. Jacquod, and **B.J. LeRoy,** *Nature Physics* **8**, 382 (2012).

9. "Scanning tunnelling microscopy and spectroscopy of ultra-flat graphene on hexagonal boron nitride" J. Xue, J. Sanchez-Yamagishi, D. Bulmash, P. Jacquod, A. Deshpande, K. Watanabe, T. Taniguchi, P. Jarillo-Herrero, and **B.J. LeRoy**, *Nature Materials* **10**, 282 (2011).

10. "Spatially resolved spectroscopy of monolayer graphene on SiO_2" A. Deshpande, W. Bao, F. Miao, C.N. Lau, and **B.J. LeRoy**, *Physical Review B* **79**, 205411 (2009). (Selected as Editor's Choice and featured in May 2009 issue of Physics)

Synergistic Activities

- Redesigned undergraduate physics labs and developed group activities for introductory physics courses at the University of Arizona.
- Worked with Physics Factory as part of NSF CAREER grant to design demonstrations for local schools.
- Two high school students worked in the lab through the High School Apprenticeship Program of the Army Research Office.
- Reviewer for Physical Review, Nature Publishing Group, Institute of Physics, American Chemical Society and other publishers. Also serve as a reviewer for ARO, DOE and NSF.
- Associate Editor for *APL Materials* and Editorial board member for Nature Publishing Group journal, *Scientific Reports.*

BIOGRAPHICAL SKETCH
Prof. Srinivas Manne

Department of Physics
University of Arizona
Tucson AZ 85721

Phone: (520) 626-5305
Fax: (520) 621-4721
E-mail: smanne@physics.arizona.edu

EDUCATION

Ph.D. in Physics, University of California at Santa Barbara, March 1994
B.S. in Engineering Physics, University of Arizona, December 1983

HONORS AND AWARDS

Department of Physics Outstanding Undergraduate Teaching Award, 2013 and 2010
Nominated for the UA College of Science Teaching Award (2012) and Koffler Teaching Prize (2011)
NSF CAREER Award, 2001
College of Science Distinguished Teaching Award, University of Arizona, 2000
Langmuir Award, American Chemical Society (Colloid & Surface Science Division), 1998
Procter & Gamble University Exploratory Research Program Award, 1998

PROFESSIONAL EXPERIENCE

2003-present	Associate Professor, Department of Physics, University of Arizona
1997-2003	Assistant Professor, Department of Physics, University of Arizona
1995-1997	Staff Scientist, Princeton Materials Institute, Princeton University
1994-1995	Alexander von Humboldt Postdoctoral Fellow, Biophysics Research Group, Department of Physics, Technical University of Munich, Germany

Note: In Fall 2009 my departmental workload switched to full-time teaching, outreach and REU

FIVE RELEVANT PUBLICATIONS

(***** indicates undergraduate research students)

E.S. Ulrich, **C.M. Limbach*** and S. Manne, “Imaging Microflows and Nanopore Structures Using Hydrodynamic Force Microscopy,” *Applied Physics Letters* 93 (2008) 243103.

A.E. Murdaugh, M. Liddelow, **A.M. Schmidt*** and S. Manne, “Two-Dimensional Crystal Growth From Undersaturated Solutions,” *Langmuir* 23 (2007) 5852-5856.

M.B. Hay*, R.K. Workman and S. Manne, “Two-Dimensional Condensed Phases from Particles with Tunable Interactions,” *Phys. Rev. E* (2003) 012401.

M.B. Hay*, R.K. Workman and S. Manne, “Mechanisms of Metal Ion Sorption on Calcite: Composition Mapping by Lateral Force Microscopy,” *Langmuir* 19 (2003) 3727-3740. (Selected for cover article)

R.K. Workman, **A.M. Schmidt*** and S. Manne, “Detection of a Diffusive 2D Gas of Amphiphiles by Lateral Force Microscopy,” *Langmuir* 19 (2003) 3248-3253.

FIVE OTHER SIGNIFICANT PUBLICATIONS

A.E. Murdaugh and S. Manne, "Friction Dependence on Growth Conditions in Epitaxial Films," *Langmuir* 25 (2009) 9792-9796.

T. Jutarosaga, S. Manne and S. Seraphin, "Si-SiO_2 Interface Formation in Low-Dose, Low-Energy Separation by Implanted Oxygen Materials," *Applied Surface Science* 250 (2005) 168-181.

R.K. Workman and S. Manne, "Molecular Transfer and Transport in Non-Covalent Microcontact Printing," *Langmuir* 20 (2004) 805-815.

R.K. Workman and S. Manne, "Patterned Water Films on Mica," *Langmuir* 18 (2002) 661-666.

R.K. Workman and S. Manne, "Variable Temperature Fluid Stage" *Rev. Sci. Instrum.* 71 (2000) 431-436.

SYNERGISTIC ACTIVITIES

Participated in two REU conferences: NSF Pan-REU Workshop (April 28-30, 2016, in Arlington VA) and APS REU Physics Site Director Workshop (Oct. 20-21, 2016, in Houston TX). These workshops shared best practices, discussed challenges and came up with several practical solutions, including common acceptance dates, nationwide database of REU offers and acceptances, and strategies for applicant sharing among REU programs. The PI led an effort to find a common REU assessment tool for physics REU programs, engaged with other site leaders by teleconference, and recommended sections of the validated URSSA questionnaire.

Lead faculty organizer for annual all-day Physics Open House in March. Scheduled public lab tours and a public lecture, designed new demos and activities, recruited students for public outreach, and coordinated with other campus facilities.

Developed and taught a new conceptual physics and chemistry course for non-majors, "The Science of Good Cooking," which attracted 300 students in its first three course offerings. Introduced conceptual foundations of mechanics, electromagnetism, heat flow, phase changes and materials properties, by applying these ideas to cooking and preservation of foods.

Developed a summer physics workshop (2013) for training K-5 schoolteachers in basic physics. Used inquiry-based approach for teachers to learn basic mechanics, materials physics and thermodynamics through experiments and collaborative reasoning.

Faculty mentor for Women in Physics (WiP), organized by grads with strong undergrad and faculty involvement.

Developed outreach course, "Communicating Physics" (2009), to train undergrads in K-12 outreach

Developed a graduate course, "Intermolecular Forces and Self-Assembly" (2000), incorporating theory and hands-on experiments with atomic force microscopy.

Mentored over 40 undergraduate research projects over 20 years of teaching.

COLLABORATIONS AND OTHER AFFILIATIONS

No collaborators in past 48 months, other than those included in publication list

<u>Advisors</u>

Graduate Advisor: Prof. P.K. Hansma, Department of Physics, University of California, Santa Barbara
Postdoctoral Advisor: Prof. H.E. Gaub, Department of Physics, University of Munich, Germany

<u>Former Graduate Students (5)</u>

Anne Murdaugh (Physics Ph.D. 2009), Elaine Ulrich (Optical Sci. Ph.D. 2008), Mary Liddelow (Matls. Sci. M.S. 2006), Rick Workman (Materials Science Ph.D. 2004), Geoff Wathen (Physics M.S. 2003)

BIOGRAPHICAL SKETCH
Sumitendra Mazumdar

Education and Training:

M.Sc. (Chemistry), I.I.T. Kanpur, India (1975).
Ph.D. (Chemistry), Princeton University (1980).
Postdoctoral Fellow, Exxon Research and Engineering Company, NJ, 1980 - 1982.
Directir's Funded Postdoctoral Fellow, Los Alamos National Laboratory, NM, 1982 - 1985.

Research and Professional Positions:

02/2009 - Head, Department of Physics, University of Arizona.
10/2013 - Professor of Physics, Chemistry, and Optical Sciences, University of Arizona.
8/97 - Professor of Physics and Optical Sciences, University of Arizona.
8/93 - 7/97, Associate Professor of Optical Sciences, University of Arizona.
8/88 - 7/97, Associate Professor of Physics, University of Arizona.
4/87 - 8/88, Scientist E, National Chemical Laboratory, Pune, India.
10/85 - 12/86, Member of Technical Staff, GTE Laboratories, Waltham, MA.

Recent Publications:

1. R. Torsten Clay and S. Mazumdar, "From charge- and spin-ordering to superconductivity in the organic charge-transfer solids," arXiv:1802.01551, Physics Reports (solicited review, submitted).
2. S. Khan and S. Mazumdar, "Theory of Transient Excited State Absorptions in Pentacene and Derivatives: Triplet-Triplet Biexciton versus Free Triplets," J. Phys. Chem. Lett. **8**, 5943-5948 (2017).
3. S. Khan and S. Mazumdar, "Diagrammatic Exciton Basis Theory of the Photophysics of Pentacene Dimers," J. Phys. Chem. Lett. **8**, 4468-4478 (2017).
4. U. N. V. Huynh, T. P. Basel, E. Ehrenfreund, G. Li, Y. Yang, S. Mazumdar and Z. V. Vardeny, "Transient Magnetophotoinduced Absorption Studies of Photoexcitations in π-Conjugated Donor-Acceptor Copolymers," Phys. Rev. Lett. **119**, 017401 (2017).
5. R. T. Clay, A. B. Ward, N. Gomes, S. Mazumdar, "Bond patterns and charge order amplitude in 1/4-filled charge-transfer solids," Phys. Rev. B 95, 125114 (2017).
6. W. Wasanthi De Silva, N. Gomes, S. Mazumdar, R. T. Clay, "Coulomb enhancement of superconducting pair-pair correlations in a 3/4-filled model for κ-(BEDT-TTF)$_2$X", Phys. Rev. B 93, 205111 (2016).
7. Niladri Gomes, W. Wasanthi De Silva, Tirthankar Dutta, R. Torsten Clay, Sumit Mazumdar, "Coulomb Enhanced Superconducting Pair Correlations in the Frustrated Quarter-Filled Band," Phys. Rev. B 93, 165110 (2016).
8. V. M. L. Durga Prasad Goli, Suryoday Prodhan, Sumit Mazumdar, S. Ramasesha, "Correlated Electronic Properties of Some Graphene Nanoribbons: A DMRG Study," Phys. Rev. B 94, 035139 (2016).
9. Karan Aryanpour, Tirthankar Dutta, Uyen N. V. Huynh, Zeev Valy Vardeny, Sumit Mazumdar, "Theory of Primary Photoexcitations in Donor-Acceptor Copolymers," Phys. Rev. Lett. 115, 267401 (2015).
10. Karan Aryanpour, Alok Shukla, Sumit Mazumdar, "Theory of Singlet Fission in Polyenes, Acene Crystals and Covalently Linked Acene Dimers," J. Phys. Chem. C 119, 6966-6979 (2015).

Synergistic Activities:

1. Panel Member, NSF DMREF initiative, Panel on Condensed Matter / Emergent Phenomena, 2017.
2. Panel Member, NSF CHE - Chem Struct,Dynamics & Mechansms A, 2015.
3. Member of Organizing Committees, International Conference on Synthetic Metals 1996, 2012, 2014, 2016, 2018.
4. Organizer of Invited Session "Excitons in semiconducting single-walled carbon nanotubes," March meeting of the American Physical Society 2006.
5. Divisional Associate Editor, Physical Review Letters, 1999 - 2001.

Collaborators during the past 48 months:

Zeev V. Vardeny, University of Utah. Eitan Ehrenfreund, Technion, Israel (Emeritus). Suryanarayana Ramasesha, Indian Institute of Science, Bengaluru, India. Alok Shukla, Indian Institute of Technology, Mumbai, India. Karan Aryanpour, Raytheon Corp., Tucson, AZ. Rudolf T. Clay, Mississippi State University. Suryoday Prodhan, Indian Institute of Science, Bengaluru, India. Tirthankar Dutta, Beijing Computational Science Research Center, Beijing, China. Uyen N. V. Huynh, Cambridge University, Cambridge, UK. Tek P. Basel, University of Utah. Gang Li, Hong Kong Polytechnical University. Yang Yang, UCLA. Wasanthi De Silva, Sri Lanka. Niladri Gomes, GlobalFoundries, Albany, NY.

Coeditors:

None.

Ph.D. Thesis Advisor:

Zoltan G. Soos, Princeton University (Emeritus)

Postdoctoral Sponsors:

Aaron N. Bloch (deceased). David K. Campbell (Boston University).

Graduate students and postdoctoral fellows supervised:

Dandan Guo (self-employed). Kim-Chau Ung (deceased). Fangyeong Guo (Taiwan). Michael Chandross (Sandia National Laboratory, Albuquerque). Zhendong Wang (Cleveland Clinic, Weston FL). Hongtao Li (unknown), Niladri Gomes (Global Foundries, Albany NY), Sourotosh Khan (current).

Dr. Yukihiro Shimoi (AIST, Japan). Dr. Aparna Chakrabarti (Raja Ramanna Centre for Advanced Technology. Indore, India). Dr. Haranath Ghosh (Raja Ramanna Centre for Advanced Technology. Indore, India). Dr. Alok Shukla (Indian Institute of Technology, Mumbai). Dr. R. Torsten Clay (Mississippi State University). Dr. Hongbo Zhao (University of Arizona), Dr. Demetra Psiachos (Crete), Dr. Karan Aryanpour (Raytheon, Tucson), Dr. Tirthankar Dutta (Beijing Computational Science Research Center, China).

Biographical Sketch

Stefan Meinel

Department of Physics
University of Arizona
1118 E 4th Street
Tucson, AZ 85721

Phone: 520-621-2453
Fax: 520-621-4721
Email: smeinel@email.arizona.edu

Appointments

2014 – present	Assistant Professor, Department of Physics, University of Arizona
2014 – present	RHIC Physics Fellow, RIKEN BNL Research Center
2012 – 2014	Senior Postdoctoral Associate, Massachusetts Institute of Technology
2010 – 2012	Postdoctoral Research Associate, College of William & Mary

Professional Preparation

2010	Ph.D., Theoretical Physics, University of Cambridge
2006	Part III of the Mathematical Tripos, University of Cambridge
2004	Vordiplom, Physics, University of Heidelberg

Ten Significant Publications

1. S. Meinel, "$\Lambda_c \to N$ form factors from lattice QCD and phenomenology of $\Lambda_c \to n\ell^+\nu_\ell$ and $\Lambda_c \to p\mu^+\mu^-$ decays," submitted to Phys. Rev. D [arXiv:1712.05783].

2. C. Alexandrou *et al.*, "P-wave $\pi\pi$ scattering and the ρ resonance from lattice QCD," Phys. Rev. D **96**, 034525 (2017) [arXiv:1704.05439].

3. S. Meinel, "$\Lambda_c \to \Lambda\ell^+\nu_\ell$ form factors and decay rates from lattice QCD with physical quark masses," Phys. Rev. Lett. **118**, 082001 (2017) [arXiv:1611.09696].

4. W. Detmold, S. Meinel, "$\Lambda_b \to \Lambda\ell^+\ell^-$ form factors, differential branching fraction, and angular observables from lattice QCD with relativistic b quarks," Phys. Rev. D **93**, 074501 (2016) [arXiv:1602.01399].

5. J. Green *et al.*, "High-precision calculation of the strange nucleon electromagnetic form factors," Phys. Rev. D **92**, 031501 (Rapid Communications) (2015) [arXiv:1505.01803].

6. W. Detmold, C. Lehner, S. Meinel, "$\Lambda_b \to p\ell^-\bar{\nu}_\ell$ and $\Lambda_b \to \Lambda_c\ell^-\bar{\nu}_\ell$ form factors from lattice QCD with relativistic heavy quarks," Phys. Rev. D 92, 034503 (2015) [arXiv:1503.01421].

7. Z. S. Brown, W. Detmold, S. Meinel, K. Orginos, "Charmed bottom baryon spectroscopy from lattice QCD," Phys. Rev. D **90**, 094507 (2014) [arXiv:1409.0497].

8. R. R. Horgan, Z. Liu, S. Meinel, M. Wingate, "Calculation of $B^0 \to K^{*0}\mu^+\mu^-$ and $B_s^0 \to \phi\,\mu^+\mu^-$ observables using form factors from lattice QCD," Phys. Rev. Lett. **112**, 212003 (2014) [arXiv:1310.3887].

9. W. Detmold, C.-J. D. Lin, S. Meinel, "Axial couplings and strong decay widths of heavy hadrons," Phys. Rev. Lett. **108**, 172003 (2012) [arXiv:1109.2480].

10. S. Meinel, "Bottomonium spectrum at order v^6 from domain-wall lattice QCD: Precise results for hyperfine splittings," Phys. Rev. D **82**, 114502 (2010) [arXiv:1007.3966].

Professional Service

Conference Organization

Chair, Workshop on Multi-Hadron and Nonlocal Matrix Elements in Lattice QCD, Brookhaven National Laboratory, 2015 (http://www.bnl.gov/mnme2015/)

Peer Review

Proposal reviewer for the National Science Foundation and for the Department of Energy

Journal referee for Physical Review Letters, Physical Review D, Journal of High Energy Physics, European Physical Journal C, Annals of Physics, Nuclear Physics B, Physics Letters B

Fulvio Melia

Professor of Physics, Astronomy, and the Applied Math Program, The University of Arizona
Editor of the Series in Theoretical Astrophysics, University of Chicago Press
Professorial Fellow, School of Physics, Melbourne University, Australia
Phone: Office: (520) 621-9651, Mobile: (520) 977-8269, Home: (520) 797-2592
Website: http://www.physics.arizona.edu/~melia

Education

1985 MIT, *Ph.D. Physics*.

Honors and Awards

Distinguished Professor, Chinese Academy of Sciences, Purple Mountain Observatory, 2012-present.
Walter Stibbs Visiting Chair, Sydney University, 2014.
Simpson Chair, Amherst College (formerly held by Niels Bohr and Robert Frost), 2010 - 2011.
PROSE Award, *Cracking the Einstein Code*, AAP 2009.
Sir Thomas Lyle Fellow (Australia) for Distinguished International Visitors, 2008.
Erskine Fellow, University of Canterbury, Christchurch, New Zealand, 2007.
Professorial Fellow, School of Physics, Melbourne University, Australia 2005 - present.
Year's Best Astronomy Book worldwide, *The Edge of Infinity*, Astronomy 2005 Special Issue.
Outstanding Book Award, *The Black Hole at the Center of Our Galaxy*, Am. Library Association 2004.
Fellow of the American Physical Society, 2002 - present.
Miegunyah Fellow (Australia) for Distinguished Fundamental Researchers, 1999 - 2001.
Sir Thomas Lyle Fellow (Australia) for Distinguished International Visitors, 1998 - 1999.
Alfred P. Sloan Research Fellow (Physics), 1989 - 1992.
Presidential Young Investigator Award (Physics), 1988 - 1994.
Arthur H. Compton Fellow, Enrico Fermi Institute, University of Chicago, 1987.

Books Published

Cracking the Einstein Code, Fulvio Melia (The University of Chicago Press, September 2009)
High-Energy Astrophysics, Fulvio Melia (Princeton University Press, February 2009)
The Galactic Supermassive Black Hole, Fulvio Melia (Princeton University Press, May 2007)
The Edge of Infinity: Supermassive Black Holes in the Universe, Fulvio Melia (Cambridge U Press, 2003)
The Black Hole at the Center of Our Galaxy, Fulvio Melia (Princeton University Press, April 2003)
Electrodynamics, Fulvio Melia (The University of Chicago Press, September 2001)

Current Appointments

Professor, Department of Physics, Steward Observatory & Applied Math, U Arizona, August 1994 - present.
Professorial Fellow, School of Physics, University of Melbourne, 2005-present.
Series Editor for Theoretical Astrophysics, The University of Chicago Press, December 2004 - present.
Member of ERC, 2015-present.

Previous Appointments

Simpson Chair, Amherst College, 2010-2012.
Associate Editor, The Astrophysical Journal Letters, 2002 - 2007.
Scientific Editor, The Astrophysical Journal, 1996 - 2002.
Assoc. Head, Dept. of Physics, University of Arizona, August 1995 – 2005.

Research Program (1987-2018)

As a core member of the Theoretical Astrophysics Program at the University of Arizona, I have been the principal investigator and leader of the group working on problems in high-energy astrophysics, general relativity, and cosmology for almost 3 decades. During this period, our group has involved 16 PhD students, 8 undergraduate students, and 5 postdoctoral fellows, in addition to many visiting scientists from Europe and Australia. Our sources of funding have included (1) the National Science Foundation, (2) The Alfred P. Sloan Foundation, (3) NASA, (4) The US Department of Education, and (5) the Office of Naval Research. Several metrics may be used to gauge the success of our group's program, including the number of former students who are now professors in universities around the world (7 in the US, Europe, Australia, India and China), the number of our students who were granted prestigious competitive awards, including NASA and NSF research fellowships (8) and the Trumpler award (1), and the impact our research has had on future directions in Astronomy and Astrophysics. In particular, our group created the idea for imaging the event horizon surrounding the black hole at the Galactic center, which has now blossomed into the Event Horizon Telescope, an international collaboration to build the next generation mm/sub-mm telescope array.

Professional Affiliations

Fellow of the American Physical Society
Member of the American Association for the Advancement of Science
Member of The National Association of Science Writers
Member of The International Astronomical Union
Member of The American Astronomical Society
Member of The American Association of University Professors

Bibliography (10 **most significant recent papers in *Refereed* Journals)**

[1] *Astronomy & Astrophysics*, in press (2018): "Evidence of a truncated spectrum in the angular correlation function of the cosmic microwave background," **Fulvio Melia and Martin Lopez-Corredoira** [DOI:10.1051/0004-6361/201732181]
[2] *The Astrophysical Journal*, **846,** 129 (2017): "Unseen Progenitors of Luminous High-z Quasars in the R_h=ct Universe," **Marco Fatuzzo and Fulvio Melia** [DOI:10.3847/1538-4357/aa8627]
[3] *Monthly Notices of the Royal Astronomical Society Letters*, **463,** (1) L61 (2016): "Definitive Test of the R_h=ct Universe Using Redshift Drift," **Fulvio Melia** [DOI: 10.1093/mnrasl
[4] *Proceedings of the Royal Society A*, **471,** 20150449 (2015): "Supermassive Black Holes in the Early Universe," **Fulvio Melia and Thomas M. McClintock** [DOI: 10.1098/rspa.2015.0449]
[5] *Monthly Notices of the Royal Astronomical Society*, **432,** 2669 (2013): "Cosmic Chronometers in the R_h=ct Universe,"**Fulvio Melia and Robert S. Maier** [DOI: 10.1093/mnras/stt596]
[6] *Astronomy & Astrophysics*, **553,** id A76 (2013): "The R_h=ct Universe Without Inflation," **Fulvio Melia** [DOI: 10.1051/0004-6361/201220447]
[7] *The Astrophysical Journal*, **764,** 72 (2013): "High-z Quasars in the R_h=ct Universe," **Fulvio Melia** [DOI: 10.1088/0004-637X/764/1/72]
[8] *Monthly Notices of the Royal Astronomical Society*, **422,** 1418 (2012): "Cosmological Redshift in FRW Metrics with Constant Spacetime Curvature," **Fulvio Melia** [DOI: 10.1111/j.1365-2966.2012.20714.x]
[9] *Monthly Notices of the Royal Astronomical Society*, **419,** 2579 (2012): "The R_h=ct Universe," **Fulvio Melia and Andrew Shevchuk** [DOI: 10.1111/j.1365-2966.2011.19906.x]
[10] *Monthly Notices of the Royal Astronomical Society*, **382,** 1917 (2007): "The Cosmic Horizon," **Fulvio Melia** [DOI: 10.1111/j.1365-2966.2007.12499.x]

Prof. Dr. Johann Rafelski

Department of Physics
The University of Arizona
PAS Bldg 81, Room 386D
1118 E. 4th Street
TUCSON, AZ 85721-0081
Contact: E-mail: Rafelski at Gmail.COM
same as: Rafelski at Physics.Arizona.Edu
Tel.: +1 520-777 9519 Cell.: +1 520-990 4213

Personal:

Born May 19, 1950 in Krakow, schooled in Poland and Germany, USA/EU citizen married with Victoria A Grossack, an author and actuary. **Children:**
Susanne M. Rafelski, Ph.D. , at Allen Institute for Cell Science; and
Marc A. Rafelski, Ph.D., at Space Telescope Science Institute (STScI)
Languages spoken fluently: English, French, German, and Polish
Hobbies: skiing, history of science

CURRENT RESEARCH INTERESTS

1. Vacuum structure and quark deconfinement and quark-gluon plasma;
2. Hadronization (creation of matter from energy) in lab and the early Universe;
3. Neutrinos in the Universe and Cosmological Evolution;
4. Strong Field and critical acceleration;
5. Physics with ultra-intense light pulses; relativistic plasma; aneutronic fusion

EDUCATION

Abitur:	1968	Goethe Gymnasium, Frankfurt/Main Prize Award	
Study:	1968--71	J.W. Goethe University, Frankfurt	\`Studienstiftung' Fellowship
Degrees:	1971	Diplom Physiker	
	1973	**Dr. Phil. Nat.**	

EMPLOYMENT HISTORY, INCLUDING MAJOR VISITING ENGAGEMENTS

CURRENT	**Professor of Physics (tenured)**	at The University of Arizona
	Member, Program in Appl. Math.	at The University of Arizona
	Affiliate, Theoretical Astrophysics	at The University of Arizona

CAREER HISTORY

1971-73	Assistent, Theoretische Physik	**J.W. Goethe Universität, Frankfurt**
1971-93	Guest Scientist	**NBS/NIST**, Washington, DC
1973-74	Postdoctoral Fellow	**University of Pennsylvania**
1974-80	Postdoctoral Fellow from 1975 Junior Staff from 1977 on leave	**Physics Division, Argonne National Laboratory, Chicago**
1977-79	Fellow	**CERN, Geneva**
1979-83	C3-Prof. für Theoretische Physik	**J.W. Goethe Universität Frankfurt**
1983-87	Chair of Theoretical Physics	**University of Cape Town**
1987	Full professor with tenure	**The University of Arizona**

MAJOR CONSULTING ENGAGEMENTS

1979-17	Guest Scientist	**CERN, Geneva:** sabbaticals 82/83, 86/87, 00/01, 04/5
1979-91	Guest Scientist	**GSI**-Darmstadt, Germany
1983-87	Scientific Advisor	MUCF research program BYU/LAMPF Los Alamos
1992	Guest Scientist	**MPI Max Planck Institut für Physik** Munich
1993-06	Guest Professor	**Universit'e Paris 7, LPTHE** sabbatical 93/94
2008-09	DFG Professor	**Munich Center for Advanced Photonics, LMU**
2010-16	Guest Professor	**LULI, Ecole Polytechnique, Palaiseau, France**
2013-16	Science Advisor	**ELI-BL** Extreme Light Infrastructure near Prague

TEACHING and PROFESSIONAL UNIVERSITY EXPERIENCE

- 40+ years lecturing with emphasis on subnuclear and foundational physics
- 35+ years supervision of graduate students/ PhD candidates
- Development of undergraduate and graduate curricula and University courses
- Worked within the US, German, French and English University systems
- Organization of international conferences, schools and seminar meetings
- Leader of multinational collaborations
- Author and co-author of major research monographs (books, major reviews)
- Editor: collective research accounts, conferences, historical perspectives

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PUBLICATIONS: overview

400+ works in theoretical: atomic, nuclear, astro particle physics, neural nets; 15 BOOKS including monographs; several popular and general interest works; among most cited work are invited papers presented at conferences which are listed seperate. **Google Scholar publications: 17,800 citations and h=62** (08/2017). A view on particle, and partial nuclear physics research writings via the Stanford Library **inSPIRES: 10,000 citations and h=48** (08/2017) .

EDUARDO ROZO

Curriculum Vitae

Department of Physics, University of Arizona
1118 E 4th St, PO Box 210081
Tucson, AZ 85721-0081, USA

Tel (office): (520) 621-2251
Tel (cell): (408)-784-1997
E-mail: erozo@email.arizona.edu

Professional Experience

2014–Present	Assistant Professor of Physics, University of Arizona.
2012–2014	Panofsky Fellow, SLAC National Accelerator Laboratory.

Postdoctoral Experience

2009–2012	Einstein Fellow, Kavli Institute for Cosmological Physics, University of Chicago.
2006–2009	CCAPP Fellow, The Ohio State University.

Education:

2000–2006	Ph.D. in Physics, University of Chicago, Chicago, IL. Advisors: Scott Dodelson and Andrey Kravtsov
1996–2000	B.A. in Physics, Bard College, Annandale-on-Hudson, NY. Advisor: Matthew Deady.

Honors, Awards, and Fellowships: Research

2018	Cottrell Scholar Award.
2016	DOE Early Career award (Office of High Energy Physics).
2016	Sloan Fellow (Physics).
2012	Panofsky Fellowship, SLAC.
2009	Einstein Fellowship.
2009	Kavli Institute for Cosmological Physics (KICP) Fellowship.
2006	Center for Cosmology and Astro-Particle Physics (CCAPP) Fellowship.
2006	Sugarman Award for Excellence in Graduate Student Research, University of Chicago.
1999	Dr. Richard M. Siegel Memorial Prize in Science, Bard College.
1998	John Bard Scholarship, Bard College.
1998	Berta and Harold J. Drescher Scholarship, Bard College.
1996–2000	Distinguished Scientist Scholarship, Bard College.
1996	Colombian representative to the XXVII International Physics Olympiad, Oslo, Norway.

Honors, Awards, and Fellowships: Teaching

2018	Cottrell Scholar Award
2016 & 2017	Excellence in Undergraduate Physics Teaching, U. of Arizona.

Leadership Positions

2017–present	Large Synoptic Survey Telescope (LSST) Dark Energy Science Collaboration (DESC): *co-chair of the Clusters working group.*
2015–2017	Dark Energy Survey (DES) collaboration: *co-chair of the Theory and Combined Probes working group, member Science Committee.*
2014–2017	Dark Energy Spectroscopic Instrument (DESI) collaboration: *co-chair of the small-scale clustering, cross-correlation, and galaxy clusters Working Group, member Science Committee.*
2014–2015	LSST Dark Energy Science Collaboration (LSST DESC): *member of the LSST DESC Collaboration Council.*

Current and Past Grants (Total: $1.332M):

When grants funded multiply people, I quote only the funds I received, not the total amount of the grant. Approximate values rounded to nearest thousand.

2018–2021	PI, Cottrell Scholar Award ($100,000).
2018–2020	coI, Chandra Calibration of the RichnessMass Relation of Galaxy Clusters. (≈ $34,000).
2017–2018	PI, Faculty Seed Grant (≈ $10,000).
2016–2020	PI, DOE Early Career Award(≈ $750,000).
2016–2017	PI, Sloan Fellowship in Physics ($50,000)
2015–2016	PI, *Chandra* Calibration of the Richness–Mass Relation of Galaxy Clusters. (≈ $38,000)
2009–2012	PI, Einstein Fellowship, NASA grant PF9-00068, (≈ $350,000).

Publication Statistics: (Computed using the NASA Astrophysics Data System citation metrics)

H-index:	38
Total Citations:	5,200+

Professional Service

Refereeing for Grant/Observing Proposals: ERC, NASA ADAP, NSERC, DOE, CFHT.

Referee for: PRL, Phys. Rev. D, ApJ, ApJL, MNRAS, A&A, NJP, JCAP.

Meetings organized: Convener for CPAD Meeting 2015, SOC 2014 *Planck* Ferrara Conference, SOC-chair for the 2014 DES collaboration meeting, 10^{th} Great Lakes Cosmology Workshop (GLCW), 8^{th} GLCW, DES Cluster Comparison workshop.

Other service: DES Meeting Steering Committee (2013-2015).

Educational and Community Outreach Activities:

2015–present	Cofounded TIMESTEP, the Tucson Initiative for Minority Engagment in STEM Program.[1]
2015–present	Faculty Mentor for the Women in Physics (WiP) student group at Arizona.[2]
2015–present	Volunteer Faculty mentor for UROC SRI[3], LASRP[4]
2016	Volunteer Presenter for the Tucson Association of Physics Teachers.
2016	Dark Energy Survey Education and Public Outreach (DES EPO) Champion.

[1]TIMESTEP seeks to improve minority engagement and retention in Physics and Astronomy through improved mentoring and frank discussions of issues affecting minorities and first generation students.

[2] WiP was recently awarded the Excellence in STEM Diversity Award by the Women in Science and Engineering (WISE) program at the University of Arizona.

[3]UROC SRI is a summer research program designed to encourage participants to pursue post-graduate education. Most UROC SRI students are low-income, first generation, or URM students. 75% of UROC SRI participants have gone on to graduate school, medical school, law, or other post-baccalaureate programs.

[4]LASRP is modeled after UROC SRI, but targets latin-american students from Honduras, Mexico, Chile, Colombia, and Brazil. The LASRP program has been recognized at a national level by NAFSA: Association of International Educators with its Paul Simon Spotlight award in 2012.

Invited Talks at International Conferences, 2015-2017 only:

October 2017	The Dark Universe, Munich, Germany.
December 2016	Cluster Cosmology, Cambridge, UK.
November 2016	Origin of the Invisible Sector, India.
June 2016	Neutrinos and Light Particles in Cosmology, UC Berkeley, CA.
June 2016	Hot spots in the XMM sky: Cosmology from X-ray to Radio, Mykonos, Greece.
April 2016	Next Generation Sky Surveys and Big Data, Daejeon, Korea.
August 2015	International Astronomical Union, Honolulu, Hawaii.
July 2015	Theoretical and Observational Progress on Large-scale Structure, Munich, Germany.
March 2015	Snowcluster, Salt Lake City, Utah.

January 2018

JOHN P. RUTHERFOORD
Professor of Physics
Physics Department
University of Arizona
Tucson, AZ 85721
rutherfo@physics.arizona.edu

BIOGRAPHICAL SKETCH

Education

Ph.D. in HEP Experiment, Cornell University, Spring 1968
(Prof. John DeWire and Dr. Eugene Loh, Advisors)
B.S. in Physics, Union College, Spring 1964

Employment

Professor, University of Arizona, 1988 – present
Professor, University of Washington, 1986 – 1988
Research Professor, University of Washington, 1985 – 1986
Research Associate Professor, University of Washington, 1979 – 1985
Research Assistant Professor, University of Washington, 1976 – 1979
Assistant Professor, Tufts University, 1969 – 1976
Research Associate, Tufts University, 1968 – 1969

Service

Fermilab Users Executive Committee 1978 – 1981 and 1990 – 1993, Chair 1979 – 1980 and 1991 – 1992.
Fermilab Physics Advisory Committee 1987 – 1991.
Elected to the Executive Committee of the American Physical Society Division of Particles and Fields 1994 – 1997.

Leadership positions

Spokesperson: Recoil Proton Polarization in Neutral Pion Photoproduction, Cornell 1970 - 1971.
Spokesperson: Large Angle Compton Scattering (TUMM), Cornell 1975 – 1976
Deputy Spokesperson: High-Mass Dimuons (E439), Fermilab 1976-1979
Chair of Fermilab Users Executive Committee 1979 – 1980 and 1991 - 1992
Spokesperson: High resolution dimuon production in proton – nucleus collisions, (E605) Fermilab , 1984 – 1985.
Fermilab Program Advisory Committee 1986 - 1991
APS/DPF Executive Committee 1995 - 1997
Project Leader: ATLAS Forward Calorimeter Construction Project, 1994 – 2005.
Chair: Group Representatives of the ATLAS Liquid Argon Unit, May 2009 – 2011 and 2011 – 2013.
Chair: Search committee for US ATLAS leadership, 2011 - 2012.

Intellectual leader of the HiLum R&D Project at IHEP, Protvino 2005 – present.
Deputy US ATLAS Institution Board Chair 2014 – 2015
US ATLAS Institution Board Chair 2016 – 2017

Selected Publications

M.A.Shupe, R.H.Milburn, D.J.Quinn, J.P. Rutherfoord, A.R.Stottlemyer, S.S.Hertzbach, R.Kofler, F.D.Lomanno, M.S.Z.Rabin, M.Deutsch, M.M.White, R.S.Galik, R.H.Siemann, "Proton Compton Scattering and Neutral Pion Photoproduction at Large Angles", Phys. Rev. Lett. **40**, 271 (1978). Experiment spokesperson and chief author.

D.A.Garelick, P.S.Gauthier, M.J.Glaubman, E.W. King, M.Mallary, J.Moromisato, E.Pothier, E. von Goeler, R. Weinstein, G.S. Hicks, P.M. Mockett, J.P. Rutherfoord, S.Smith, R.W.Williams, W.P. Oliver, "Confirmation of an enhancement in the $\mu^+\mu^-$ mass spectrum at 9.5 GeV", Phys. Rev. **D18**, 945 (1978). Experiment deputy spokesperson and chief author.

J.Rutherfoord, "Hadronic Production of Real and Virtual Photons", Proceedings of the 1985 International Symposium on Lepton and Photon Interactions at High Energies, August 19-24, 1985, Kyoto, p662. Plenary review talk and proceedings. Sole author.

J.Rutherfoord (with C.N.Brown *et al.*), "Dimuon Production in 800 GeV Proton-Nucleus Collisions", Phys. Rev. Lett. **63**, 2637 (1989). Experiment spokesperson and lead author.

J.Rutherfoord (with the ATLAS Liquid Argon Group), "ATLAS Liquid Argon Calorimeter Technical Design Report", CERN/LHCC/96-41, December 1996. Chapter author.

J.Rutherfoord, "The ATLAS Forward Calorimeters", Proceedings of the Sixth International Conference on Calorimetry in High Energy Physics", Ed. A.Antonelli, S.Bianco, A.Calcaterra, F.L.Fabbri, Frascati, June 1996. Talk at opening session.

J.Rutherfoord, "Signal degradation due to charge buildup in noble liquid ionization calorimeters", Nucl. Instrum. and Meth. **A482** (2002) 156. Sole author.

J.Rutherfoord (with the ATLAS Forward Calorimeter collaboration. A. Artamonov *et al.*), "The ATLAS Forward Calorimeter", 2008 JINST 3 P02010. Project leader and primary author.

B.Toggerson, A.Newcomer, J. Rutherfoord, and R.B.Walker, "Onset of space charge effects in liquid argon ionization chambers", Nucl. Instrum. and Meth. A 608 (2009) 238. Sole author.

J.Rutherfoord, A.Savine, L.Shaver, R.Walker *et al*., "Relative luminosity measurement of the LHC with the ATLAS forward calorimeter", 2010 JINST 5 P05005. One of several authors.

J.Rutherfoord, A.Savine, L. Shaver, R.Walker, *et al*., "Liquid argon calorimeter performance at high rates", Nucl. Instrum. and Meth. A 669 (2012) 47. One of two authors.

J.Rutherfoord and R.B.Walker, "Space-charge effects in liquid argon ionization chambers", Nucl. Instrum. and Meth. A 776 (2015) 65. Sole author.

Arvinder Sandhu
Dept. of Physics and College of Optical Sciences, University of Arizona, Tucson, Arizona 85721

Education and Training

G. N. D. University, India	Physics	B.Sc.	1996
Indian Institute of Technology, Kanpur	Physics	M.Sc.	1998
Tata Institute of Fundamental Research	Physics	Ph.D.	2005

Research and Professional Service

Associate Professor, Physics and Optical Sciences, Univ. of Arizona	2013-Present
Assistant Professor, Physics and Optical Sciences, Univ. of Arizona	2007- 2013
Adjunct Faculty, Indian Inst. of Sci. Edu. and Res., Mohali, India	2010-2013
Senior Research Associate, JILA, University of Colorado	2006-2007
Research Associate, JILA, University of Colorado	2004-2006
Research Assistant, Tata Inst. of Fundamental Research, Mumbai	1998-2004

Awards

2017 Distinguished Scholar Award, The University of Arizona.
2010 Excellence in Undergraduate Physics Teaching, Dept. of Physics, University of Arizona.
2010 NSF Career Award, National Science Foundation, USA.
2007 Young Scientist Medal, Indian National Science Academy, New Delhi, India.
2005 Tata Alumni Award, Outstanding Ph.D. thesis, Tata Inst. of Fundamental Research.

Selected Publications

1. H. Timmers, Z. Li, N. Shivaram, R. Santra, O. Vendrell, and A. Sandhu, "*Coherent electron hole dynamics near a conical intersection*" Phys. Rev. Lett. **113,** 113003 (2014).
2. C-T. Liao, X. Li, D. Haxton, T. Rescigno, R. Lucchese, C. McCurdy, A. Sandhu, *"Probing autoionizing states of molecular O_2 with XUV transient absorption: Electronic symmetry dependent lineshapes and laser induced modification"* Phys. Rev. A **95**, 043427 (2017).
3. C.-T. Liao, A. Sandhu, S. Camp, K. Schafer, M. Gaarde, "*Beyond the Single-Atom Response in Absorption Line Shapes: Probing a Dense, Laser-Dressed Helium Gas with Attosecond Pulse Trains*" Phys. Rev. Lett. **114**, 143002 (2015).
4. N. Shivaram, H. Timmers, X.-M. Tong, and A. Sandhu, "*Attosecond-resolved evolution of a laser-dressed Helium atom: Interfering excitation paths and quantum phases*" Phys. Rev. Lett. **108**, 193002 (2012).
5. H. Timmers, N. Shivaram, and A. Sandhu, "*Ultrafast dynamics of neutral superexcited Oxygen: A direct measurement of the competition between autoionization and predissociation*" Phys. Rev. Lett. **109**, 173001 (2012).
6. E. Gagnon, P. Ranitovic, X.-M. Tong, L. Cocke, M. Murnane, H. Kapteyn and A. Sandhu, "*Soft X-ray driven femtosecond molecular dynamics*", Science **317**, 1374 (2007).

7. A. Roberts, R. Binder, N. Kwong, D. Golla, D. Cormode, B. LeRoy, H. Everitt, and A. Sandhu, "*Optical characterization of electron-phonon interactions at the saddle point in graphene*", Phys. Rev. Lett. **112**, 187401 (2014).
8. D. Golla, A. Brasington, B. LeRoy, A. Sandhu, "*Ultrafast relaxation of hot phonons in graphene-hBN heterostructures*", APL Materials **5**, 056101 (2017).
9. N. Shivaram, X.-M. Tong, H. Timmers and A. Sandhu, *"Attosecond quantum-beat spectroscopy in helium"*, J. Phys. B: At., Mol. Opt. Phys. **49**, 055601 (2016).
10. A. Roberts, D. Cormode, C. Reynolds, T. Newhouse-Illige, B. LeRoy, A. Sandhu, "*Response of graphene to femtosecond high-intensity laser irradiation*" Appl. Phys. Lett. **99**, 051912 (2011).

Synergistic activities

- Co-Organizer for the 2017 ITAMP/B2 Winter School on "Quantum Information: Fundamentals and Applications" at Biosphere 2 in Tucson AZ (January 4-11, 2017).
- Discussion leader, Gordon Conference on Multiphoton processes, Waltham MA (2014).
- Chair, Attosecond Transient Absorption Session, DAMOP 2014, Madison, WI (2014).
- Editorial Board Member, Journal of Lasers, Optics & Photonics (2014).
- Conducted 'Physics Day' demonstrations at the University of Arizona on "Blasting Atoms with Attosecond Photon Torpedos" (March 2012, 2013, 2014, and 2016).

Collaborators and Coeditors

Prof. Steve Leone (University of California, Berkeley)
Prof. Bill McCurdy (University of California, Davis)
Prof. Robert Lucchese (Texas A&M)
Prof. Robin Santra (CFEL, Germany)
Prof. Ken Schafer (Lousiana State University)
Prof. Mette Garde (Lousiana State University)
Prof. Brian Leroy (University of Arizona)
Prof. Sumit Mazumdar (University of Arizona)
Dr. Henry Everitt (Army, AMRDEC, Redstone Arsenal AL)
Prof. Rajendra Rathore (Marquette University)
Prof. Rolf Binder (University of Arizona),
Prof. Xiao-Min Tong (University of Tsukuba)

Graduate and Postdoc Advisors and Advisees

Post-doctoral Advisor(s): Prof.'s Henry Kapteyn and Margaret Murnane (Univ. of Colorado)
Graduate Advisor: Prof. G. Ravindra Kumar (Tata Institute Fundamental Research, India).

Graduate Advisees

Adam Roberts (Northrup Grumman Inc.)
Niranjan Shivaram (Lawrence Berkeley Laboratory).
Henry Timmers (NIST, Boulder)
Chen-Ting Liao (JILA, CU Boulder)
Dheeraj Golla (Cymer Inc., San Diego)

INA SARCEVIC

EDUCATIONAL BACKGROUND:

1981	B.S., Physics (with highest honors), University of Sarajevo, Bosnia
1986	Ph.D., Physics, University of Minnesota; (Ph.D. advisor: S. Gasiorowitz)

PROFESSIONAL EMPLOYMENT:

1999–present	Professor, Department of Physics, University of Arizona
2006–present	Professor, Department of Astronomy, University of Arizona
2000–present	Member of the Theoretical Astrophysics Program, University of Arizona
2009	Visiting Professor, Department of Physics, Brown University
1993–1999	Associate Professor, Department of Physics, University of Arizona
1994	Visiting Associate Professor, Department of Physics and Astronomy, The Johns Hopkins University
1988–1993	Assistant Professor, Department of Physics, University of Arizona
1986–1988	Director's Postdoctoral Fellow, Los Alamos National Laboratory
1984–1986	Research Assistant, University of Minnesota
1982–1984	Teaching Associate, University of Minnesota

HONORS AND AWARDS

2006–	Fellow, American Physical Society
1989–1991	Humboldt Fellowship
1985–1986	University of Minnesota Doctoral Dissertation Fellowship
1981	Summa cum laude B.S. from the University of Sarajevo
1978–1981	University of Sarajevo Fellowships

SELECTED PROFESSIONAL ACTIVITIES

1. Organizer of the Workshop on *Frontiers in Particle Physics*, Aspen Winter Conference on Particle Physics, January 25-31, 1998.

2. International Advisory Committee for the *Advances in Particle Physics, Recent Results and Open Questions*, 1999 Aspen Winter Conference, Aspen Center for Physics, Aspen, CO, January 17-23, 1999.

3. Organizer of the Workshop on *Neutrinos with Mass*, Aspen Center for Physics, Aspen, CO, June 26-July 16, 2000.

4. International Advisory Committee for the 2002 Aspen Winter Conference on *Ultra High Energy Particles from Space*, Aspen Center for Physics, Aspen, CO, Jan 27-Feb 2, 2002.

5. Chair, Neutrino/Dark Matter Session, *Conference on Elementary Particles, Astrophysics and Cosmology*, Ft. Lauderdale, Florida, December 15-20, 2011.

6. Organizer of the Workshop on *Neutrino Astrophysics and Fundamental Properties*, INT, University of Washington, Seattle, June 1-26, 2015.

Ten Selected Publications

1. "Charm Decay in Slow-Jet Supernovae as the Origin of the Icecube Ultra-High Energy Neutrino Events", (with A. Bhattacharya, R. Enberg and M. H. Reno), *JCAP* **06**, 034 (2015).
2. "Perturbative Charm Production and the Prompt Atmospheric Neutrino Flux in light of RHIC and LHC", (with A. Bhattacharya, R. Enberg, M. H. Reno and A. Stasto), *JHEP* **110**, 1506 (2015).
3. "Reconciling Neutrino Flux from Heavy Dark Matter Decay Recent Events at Icecube", (with A. Bhattacharya and M. H. Reno), *JHEP* **110**, 1406 (2014).
4. "On the Capture of Dark Matter with Neutron Stars", (with A. Erkoca, T. Guver and M. H. Reno), *JCAP* **013**, 1405 (2014).
5. "Probing Dark Matter Models with Neutrinos from the Galactic Center", (with A. E. Erkoca and M. H. Reno), *Phys. Rev.* **D82**, 113006 (2010).
6. "Muon Flux and Showers from Dark Matter Annihilation in the Galactic Center", (with A. E. Erkoca, G. Gelmini and M. H. Reno), *Phys. Rev.* **D81**, 096007 (2010).
7. "Propagation of Supersymmetric Charged Sleptons", (with M. H. Reno and S. Su), *Astropart. Phys.* **24**, 107 (2005).
8. "Neutrino Interactions at Ultrahigh-Energies", (with R. Gandhi, C. Quigg, and M.H. Reno), *Phys. Rev.* **D58**, 093009 (1998).
9. "Mini Z' Burst from Relic Supernova and Late Neutrino Masses", (with H. Goldberg and G. Perez), JHEP **0611**, 023 (2006).
10. "On Black Hole Detection with OWL/AIRWATCH Telescope", (with S. Iyer Dutta and M. H. Reno), Phys. Rev. **D 66**, 033022 (2002).

Collaborators in the last five years: Mary Hall Reno (U of Iowa), Rikard Enberg (Uppsala U, Sweden), Anna Stasto (Penn State U), Tolga Guver (Istanbul U, Turkey).

Postdocs supervised (partial list): Irina Mocioiu (Associate Professor, Penn State U), Rikard Enberg (Associate Professor at Uppsala University, Sweden), Grel Mahlon (Associate Professor, Penn State U, Mont Alto), Raj Gandhi (faculty at Harish-Chandra Insitute, India), Arjun Berera (Professor, University of Edinburgh), Jamal Jalilian-Marian (Associate Professor, Baruch College, New York City), Kostas Orginos (Associate Professor, College of William and Mary), Anastasios Taliotis (postdoc at University of Crete, Greece), Tolga Guver (Assistant Professor at Istanbul University, Turkey) and Atri Bhattacharya (postdoc at University of Liege, Belgium).

Gradute students supervised (partial list): Jessica Uscinski (Ph.D. 2008, faculty at American University), Sharara Iyer Dutta (Ph.D. 2000, faculty at CMR Institute of Technology, India), Arif Emre Erkoca (Ph.D. 2010, Managing Director at BUPAT USA).

Sarcevic has given over 200 invited talks at major international conferences, workshops, including seminars and colloquia. Served on over 50 international committees for physics conferences and workshops.

John R. Schaibley

Assistant Professor, Physics Department, University of Arizona, P.O. Box 210081, Tucson, AZ 85721-0081; (Phone) 520-626-5112; (E-mail) johnschaibley@email.arizona.edu

Professional Preparation:

Undergraduate Institution			
Purdue University	West Lafayette, IN	Physics, Mathematics	B.S. 2007
Graduate Institution			
University of Michigan	Ann Arbor, MI	Optics	M.S. EE 2009
University of Michigan	Ann Arbor, MI	Physics	Ph.D. 2013
Postdoctoral Institution			
University of Washington	Seattle, WA	Physics	2013-2016

Appointments:

Assistant Professor			
University of Arizona	Tucson, AZ	Physics	2016-Pres.

Publications:

Five most closely related

J. R. Schaibley, P. Rivera, K. L. Seyler, H. Yu, J. Yan, D. G. Mandrus, T. Taniguchi, K. Watanabe, W. Yao, X. Xu, "Directional interlayer spin-valley transfer in two-dimensional heterostructures," *Nature Communications* **7** 13747 (2016).

P. Rivera, K. L. Seyler, H. Yu, J. R. Schaibley, J. Yan, D. G. Mandrus, W. Yao, X. Xu, "Valley-polarized exciton dynamics in a 2D semiconductor heterostructure," *Science* **351** 688-691 (2016).

J. R. Schaibley, H. Yu, G. Clark, P. Rivera, J. S. Ross, K. L. Seyler, W. Yao, X. Xu, "Valleytronics in 2D materials," *Nature Reviews Materials* **1** 16055 (2016).

P. Rivera, J. R. Schaibley, A. M. Jones, J. S. Ross, S. Wu, G. Aivazian, P. Klement, N. J. Ghimire, J. Yan, D. G. Mandrus, W. Yao, X. Xu, "Observation of long-lived interlayer excitons in monolayer $MoSe_2$-WSe_2 heterostructures" *Nature Communications* **6** 6242 (2015).

S. Wu, S. Buckley, J. R. Schaibley, L. Feng, J. Yan, D. G. Mandrus, F. Hatami, W. Yao, J. Vučković, A. Majumdar, X. Xu, "Monolayer semiconductor nanocavity lasers with ultralow thresholds," *Nature* **520** 69-72 (2015).

Five other significant publications

G. Clark, J. R. Schaibley, J. S. Ross, T. Taniguchi, K. Watanabe, J. R. Hendrickson, S. Mou, W. Yao, and X. Xu, 2016. "Single Defect Light Emitting Diode in a van der Waals Heterostructure," *Nano Letters* **16** 3944–3948 (2016).

Yu-Ming He, G. Clark, J. R. Schaibley, Yu He, M.-C. Chen, Y.-J. Wei, X. Ding, Qiang Zhang, Wang Yao, Xiaodong Xu, Chao-Yang Lu, Jian-Wei Pan, "Single quantum emitters in monolayer semiconductors," *Nature Nanotechnology* **10** 497-502 (2015).

K. L. Seyler, J. R. Schaibley, P. Gong, P. Rivera, S. Wu, A. M. Jones, J. Yan, D. G. Mandrus, W. Yao, X. Xu, "Electrical control of second-harmonic generation in a WSe_2 monolayer transistor," *Nature Nanotechnology* **10** 407-411 (2015).

J. R. Schaibley, T. Karin, H. Yu, J. S. Ross, P. Rivera, A. M. Jones, M. Scott, J. Yan, D. G. Mandrus, W. Yao, K.-M. Fu, X. Xu, "Population pulsation resonances of excitonic states in monolayer $MoSe_2$ with sub 1 μeV linewidths," *Physical Review Letters* **114** 137402 (2015).

J. R. Schaibley, A. P. Burgers, G. A. McCracken, L.-M. Duan, P. R. Berman, D. G. Steel, A. S. Bracker, D. Gammon, and L.J. Sham, "Demonstration of quantum entanglement between a single electron spin confined to a single InAs quantum dot and a photon," *Physical Review Letters* **110**, 167401 (2013).

Synergistic Activities:

Reviewer for *Nature Communications, Nature Photonics, Nature Physics, Nano Letters*, *Optica*, *JOSA B, APL Materials, PRL, PRB, and 2D Materials.*

Conference chair at APS March meeting (2015, 2016), and CLEO (2016).

Host for "Physics Demo Day" at University of Arizona- Department of Physics (2017).

Participant in Society of Women in Physics Demo Days at Slauson Middle School, Ann Arbor MI (2009, 2010).

Appendix 1: Biographical Sketch
Charles A. Stafford

Education and Training

University of California, San Diego, Physics, B.A. Summa Cum Laude, 1985
Princeton University, Physics, M.A., 1989
AT&T Bell Laboratories, Theoretical Physics, Member of Technical Staff, Summers 1989–1991
Princeton University, Physics, Ph.D., 1992
University of Maryland, Physics, Postdoc, 1992–1994
University of Geneva, Theoretical Physics, Maître-Assistant, 1994–1996
University of Fribourg, Switzerland, Theoretical Physics, Maître-Assistant, 1996–1997
Albert-Ludwigs-University, Freiburg, Germany, Physics, Postdoc, 1997–1998

Professional experience

Professor of Physics, University of Arizona, 2012 to present
Associate Professor of Physics, University of Arizona, 2004–2012
Assistant Professor of Physics, University of Arizona, 1998–2004

Ten Publications Most Relevant to Proposed Project

1. Charles A. Stafford and Abhay Shastry, "Local entropy of a nonequilibrium fermion system," Journal of Chemical Physics **146**, 092324 (2016);
`http://aip.scitation.org/doi/abs/10.1063/1.4975810`

2. Abhay Shastry and Charles A. Stafford, "Temperature and voltage measurement in quantum systems far from equilibrium," Physical Review B **94**, 155433 (2016);
`http://journals.aps.org/prb/abstract/10.1103/PhysRevB.94.155433`

3. Charles A. Stafford, "Local temperature of an interacting quantum system far from equilibrium," Physical Review B **93**, 245403 (2016);
`http://journals.aps.org/prb/abstract/10.1103/PhysRevB.93.245403`

4. Abhay Shastry and Charles A. Stafford, "Cold spots in quantum systems far from equilibrium: local entropies and temperatures near absolute zero," Physical Review B **92**, 245417 (2015);
`http://journals.aps.org/prb/abstract/10.1103/PhysRevB.92.245417`

5. Justin P. Bergfield, Mark A. Ratner, Charles A. Stafford, Massimiliano Di Ventra, "Tunable Quantum Temperature Oscillations in Graphene Nanostructures," Physical Review B 91, 125407 (2015); `http://journals.aps.org/prb/abstract/10.1103/PhysRevB.91.125407`

6. J. P. Bergfield and C. A. Stafford, "Thermoelectric Corrections to Quantum Voltage Measurement," Physical Review B **90**, 235438 (2014);
`http://journals.aps.org/prb/abstract/10.1103/PhysRevB.90.235438`

7. J. Meair, J.P. Bergfield, C.A. Stafford, Ph. Jacquod, "Local Temperature of Out-of-Equilibrium Quantum Electron Systems," Physical Review B **90**, 035407 (2014);
`http://journals.aps.org/prb/abstract/10.1103/PhysRevB.90.035407`

8. Justin P. Bergfield, Shauna M. Story, Robert C. Stafford, Charles A. Stafford, "Probing Maxwell's Demon with a Nanoscale Thermometer," ACS Nano **7**, 4429-4440 (2013); `http://pubs.acs.org/doi/abs/10.1021/nn401027u`
9. J. P. Bergfield, M. Solis, and C. A. Stafford, "Giant Thermoelectric Effect from Transmission Supernodes," *ACS Nano* **4**, 5314–5320 (2010); `http://pubs.acs.org/doi/abs/10.1021/nn100490g`
10. J. P. Bergfield and C. A. Stafford, "Thermoelectric Signatures of Coherent Transport in Single-Molecule Heterojunctions," *Nano Letters* **9**, 3072–3076 (2009); `http://pubs.acs.org/doi/abs/10.1021/nl901554s`

Patents (relevant to this project)

J. Bürki, C. A. Stafford, and D. L. Stein, "Nanoscale variable resistor/electromechanical transistor," *U.S. Patent No. 9,406,789* (2016); `http://www.freepatentsonline.com/9406789.html`

Synergistic Activities

1. Founding Co-Director of the *Chemical Physics Program* at the University of Arizona, an interdisciplinary graduate program which began admitting Ph.D. students in 2010.
2. Member of Editorial Board, *Frontiers in Condensed Matter Physics.*
3. Supervised the research (for academic credit) of eight undergraduate students in the past three years, including three members of under-represented groups.
4. "Using nanotechnology to convert waste heat into electricity" TED Talk, TEDx Tucson Salon (May 12, 2015) `https://www.youtube.com/watch?v=BG8LYEqNmqk`
5. Radio interview, *Wakeup Tucson* with Chris DeSimone, KVOI 1030AM, January 5, 2017. Discussed our research on thermoelectrics and temperatures far from equilibrium.

Graduate and Postdoctoral Advisors

Ph.D. Thesis Advisor: Philip W. Anderson, Princeton University
Postdoctoral Sponsors: Sankar Das Sarma, University of Maryland; Markus Büttiker, University of Geneva (deceased); Dionys Baeriswyl, University of Fribourg, Switzerland; Hermann Grabert, Albert-Ludwigs-University, Freiburg, Germany

Graduate Students and Postdocs Supervised (past 7 years)

Justin Bergfield, Ph.D. 2010, Illinois State University; Joshua Barr, Ph.D. 2013, University of Arizona; Abhay Shastry, Ph.D. 2017 (expected), University of Arizona.

Other Collaborators During the Past 48 Months

Jérôme Bürki, California State University, Sacramento; Lincoln Carr, Colorado School of Mines; Massimiliano Di Ventra, UC San Diego; Ferdinand Evers, University of Regensburg; Lan Gong, New York University; Mark Lusk, Colorado School of Mines; Mark Ratner, Northwestern University; Daniel Stein, New York University; Jeramy Zimmerman, Colorado School of Mines

John R. Schaibley

Assistant Professor, Physics Department, University of Arizona, P.O. Box 210081, Tucson, AZ 85721-0081; (Phone) 520-626-5112; (E-mail) johnschaibley@email.arizona.edu

Professional Preparation:

Undergraduate Institution			
Purdue University	West Lafayette, IN	Physics, Mathematics	B.S. 2007
Graduate Institution			
University of Michigan	Ann Arbor, MI	Optics	M.S. EE 2009
University of Michigan	Ann Arbor, MI	Physics	Ph.D. 2013
Postdoctoral Institution			
University of Washington	Seattle, WA	Physics	2013-2016

Appointments:

Assistant Professor			
University of Arizona	Tucson, AZ	Physics	2016-Pres.

Publications:

Five most closely related

J. R. Schaibley, P. Rivera, K. L. Seyler, H. Yu, J. Yan, D. G. Mandrus, T. Taniguchi, K. Watanabe, W. Yao, X. Xu, "Directional interlayer spin-valley transfer in two-dimensional heterostructures," *Nature Communications* **7** 13747 (2016).

P. Rivera, K. L. Seyler, H. Yu, J. R. Schaibley, J. Yan, D. G. Mandrus, W. Yao, X. Xu, "Valley-polarized exciton dynamics in a 2D semiconductor heterostructure," *Science* **351** 688-691 (2016).

J. R. Schaibley, H. Yu, G. Clark, P. Rivera, J. S. Ross, K. L. Seyler, W. Yao, X. Xu, "Valleytronics in 2D materials," *Nature Reviews Materials* **1** 16055 (2016).

P. Rivera, J. R. Schaibley, A. M. Jones, J. S. Ross, S. Wu, G. Aivazian, P. Klement, N. J. Ghimire, J. Yan, D. G. Mandrus, W. Yao, X. Xu, "Observation of long-lived interlayer excitons in monolayer $MoSe_2$-WSe_2 heterostructures" *Nature Communications* **6** 6242 (2015).

S. Wu, S. Buckley, J. R. Schaibley, L. Feng, J. Yan, D. G. Mandrus, F. Hatami, W. Yao, J. Vučković, A. Majumdar, X. Xu, "Monolayer semiconductor nanocavity lasers with ultralow thresholds," *Nature* **520** 69-72 (2015).

Five other significant publications

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Yu-Ming He, G. Clark, J. R. Schaibley, Yu He, M.-C. Chen, Y.-J. Wei, X. Ding, Qiang Zhang, Wang Yao, Xiaodong Xu, Chao-Yang Lu, Jian-Wei Pan, "Single quantum emitters in monolayer semiconductors," *Nature Nanotechnology* **10** 497-502 (2015).

K. L. Seyler, J. R. Schaibley, P. Gong, P. Rivera, S. Wu, A. M. Jones, J. Yan, D. G. Mandrus, W. Yao, X. Xu, "Electrical control of second-harmonic generation in a WSe_2 monolayer transistor," *Nature Nanotechnology* **10** 407-411 (2015).

J. R. Schaibley, T. Karin, H. Yu, J. S. Ross, P. Rivera, A. M. Jones, M. Scott, J. Yan, D. G. Mandrus, W. Yao, K.-M. Fu, X. Xu, "Population pulsation resonances of excitonic states in monolayer $MoSe_2$ with sub 1 μeV linewidths," *Physical Review Letters* **114** 137402 (2015).

J. R. Schaibley, A. P. Burgers, G. A. McCracken, L.-M. Duan, P. R. Berman, D. G. Steel, A. S. Bracker, D. Gammon, and L.J. Sham, "Demonstration of quantum entanglement between a single electron spin confined to a single InAs quantum dot and a photon," *Physical Review Letters* **110**, 167401 (2013).

Synergistic Activities:

Reviewer for *Nature Communications, Nature Photonics, Nature Physics, Nano Letters, Optica, JOSA B, APL Materials, PRL, PRB, and 2D Materials.*

Conference chair at APS March meeting (2015, 2016), and CLEO (2016).

Host for "Physics Demo Day" at University of Arizona- Department of Physics (2017).

Participant in Society of Women in Physics Demo Days at Slauson Middle School, Ann Arbor MI (2009, 2010).

CURRICULUM VITAE
Shufang Su

University of Arizona
1118 E. 4th Street, P.O. Box 210081
Tucson, AZ 85721

Tel:(520)621-2866
fax:(520)621-4721
e-mail: shufang@email.arizona.edu
URL: http://www.physics.arizona.edu/~shufang

Research Area

Theoretical elementary particle physics focusing on new physics beyond Standard Model. Phenomenology of new physics models, collider searches, Higgs physics, electroweak precision analyses, dark matter and particle cosmology.

Chronology of Education

1995-2000 **Massachusetts Institute of Technology**
Ph.D. in Physics, June, 2000.
Thesis Advisor: Prof. Lisa Randall
Thesis: *Search for Supersymmetry: New Physics beyond the Standard Model*

1990-1995 **University of Science and Technology of China**
B.S. in Physics, June, 1995.
Thesis Advisor: Prof. Yunxiu Ye
Thesis: Λ *polarization in Relativistic Nucleus-Nucleus Collision*

Chronology of Employment

1995−2000 Research Assistant and Teaching Assistant
Department of Physics, Massachusetts Institute of Technology

2000−2003 John A. McCone Fellow. Postdoc Advisor: Prof. Mark Wise
Department of Physics, California Institute of Technology

2003−2009 Assistant professor
Department of Physics, University of Arizona

2009−2015 Associate professor
Department of Physics, University of Arizona

2015−present professor
Department of Physics, University of Arizona

2010−2011 Visiting professor
Department of Physics and Astronomy, University of California, Irvine

Honors and Awards

2014 **American Physics Society Fellow**
American Physics Society, Division of Particles and Fields.
For her fundamental contributions to the phenomenology of Higgs bosons, dark matter, supersymmetry, and other physics beyond the Standard Model, which have stimulated and guided experimental search programs.

2010, 2014 **Graduate Teaching Award**
Department of Physics, University of Arizona.

2013 **APS 4CS Annual Meeting Best Non-student Talk Award**
APS 4CS 2013 meeting, University of Denver.

Service

- Chair-elect of the American Physics Society (APS) Four Corners Section (2011), Chair (2012), Past Chair (2013).
- APS Committee on Scientific Publications (CSP), 2014 - 2017. Serve as committee chair starting 2015.
- Serve as Faculty Advisor of *Chinese Student and Scholar Association* at the University of Arizona.
- Serve on the Academic Committee for Center for Future High Energy Physics (CFHEP), IHEP, China.
- Serve on the advisory board for Amherst Center for Fundamental Interactions (ACFI).
- Serve on the editorial board for journals Chinese Physics C and China Science.
- Serve on several review panels of National Science Foundation and Department of Energy.

DOUG TOUSSAINT
Biographical Information
August 28, 2015

EDUCATION:

Univ. of North Carolina	Physics	BS 1974
Princeton University	Physics	Ph.D. 1978
Univ. of Calif. Santa Barbara	High Energy Physics	1978-1980
Institute for Theoretical Physics	High Energy Physics	1980-1983

APPOINTMENTS:

July 1994 - present
Professor, Department of Physics
University of Arizona, Tucson, AZ 85721

May 1997 - Aug 1997
Visiting Professor, Center for Computational Physics
University of Tsukuba, Tsukuba, Ibaraki 305, Japan

Aug. 1988 - June 1994
Associate Professor, Department of Physics
University of Arizona, Tucson, AZ 85721

Jan. 1988 - May 1988
Visiting Scientist, Fermi National Accelerator Laboratory
PO Box 500, Batavia, IL 60510

July 1983 - June 1988
Assistant Professor, Physics Department, B-019
University of California at San Diego, La Jolla, CA 92093

EXPERTISE:

Study of nonperturbative field theories through numerical simulation. In particular, simulations of Quantum Chromodynamics, including studies of the hadron spectrum, meson decay constants, heavy-light meson form factors, and vacuum structure. Also algorithm and code development to support these studies.

SELECTED PUBLICATIONS:

1. *Hybrid Molecular Dynamics Algorithms for the Numerical Simulation of Quantum Chromodynamics*, S. Gottlieb, W. Liu, R. Renken, R. L. Sugar, and Doug Toussaint, Phys. Rev. D **35**, 2531-2542 (1987).

2. *Improved flavor symmetry in Kogut-Susskind fermion actions*, K. Orginos, R. Sugar, D. Toussaint hep-lat/9909087, Nucl. Phys. B(Proc. Suppl.) **83**, 878 (2000).

3. *High-Precision Lattice QCD Confronts Experiment*, C.T.H. Davies *et al.*, hep-lat/0304004, Phys. Rev. Lett. **92** (2004) 022001.

4. *First determination of the strange and light quark masses from full lattice QCD,* HPQCD, MILC and UKQCD collaborations: C. Aubin *et al.*, Phys.Rev. D **70** (2004) 031504, [hep-lat/0405022].

5. *Light pseudoscalar decay constants, quark masses, and low energy constants from three-flavor lattice QCD,* MILC Collaboration: C. Aubin *et al.*, Phys. Rev. D **70**, 114501 (2004), [hep-lat/0407028].

6. *Full nonperturbative QCD simulations with 2+1 flavors of improved staggered quarks,* MILC Collaboration: A. Bazavov *et al.*, Rev. Mod. Phys. **82**, 1349-1417 (2010), [arXiv:0903.3598].

7. *The strange quark condensate in the nucleon in 2+1 flavor QCD,* D. Toussaint and W. Freeman [MILC collaboration], Phys. Rev. Lett. **103**, 2009, 122002, [arXiv:0905.2432].

8. *Lattice QCD ensembles with four flavors of highly improved staggered quarks,* The MILC Collaboration: A. Bazavov, *et al.*, Phys. Rev. D. **87**, 054505 (2013), [arXiv:1212.4768].

9. *Leptonic decay-constant ratio f_{K^+}/f_{π^+} from lattice QCD with physical light quarks,* MILC Collaboration: A. Bazavov *et al.*, Phys. Rev. Lett. **110**, 172003 (2013), [arXiv:1301.5855].

10. *Charmed and light pseudoscalar meson decay constants from four-flavor lattice QCD with physical light quarks,* Fermilab Lattice and MILC Collaborations: A. Bazavov *et al.*, Phys. Rev. D **90**, 074509 (2014), [arXiv:1407.3772].

Collaborators and Co-Editors

Alexei Bazavov (UC Riverside and University of Iowa), Claude Bernard (Washington Univ.), Chris Bouchard (Ohio State University), C.T.H. Davies (Glasgow University), C.E. Detar (Univ. of Utah), Daping Du (Syracuse University), Aida El-Khadra (Univ. of Illinois), Elizabeth Freeland (Art Institute of Chicago), Walter Freeman (Syracuse U.), Elvira Gamiz (Universidad de Granada), Steven Gottlieb (Indiana Univ.), Urs M. Heller (APS), Jim Hetrick (Univ. of the Pacific), Jongjeong Kim (Seoul University), Andreas Kronfeld (Fermilab), Jack Laiho (Fermilab), Ludmila Levkova (University of Utah), Paul Mackenzie (Fermilab), Ethan Neil (Colorado University), James Osborn (Argonne Nat'l Lab.), Jim Simone (Fermilab), Bob Sugar (UCSB), Ruth Van de Water (Fermilab), Ran Zhou (Fermilab)

Graduate and Postdoctoral Advisors

Frank Wilczek (MIT), R.L. Sugar (UCSB)

Students and Postdocs

W. Freeman (Syracuse U.), T. Burch (Regensburg), T. Blum (U. Connecticut), G. Buendia (U. of Caracas), W. Liu (Merrill-Lynch), J. Kim (Seoul U.) A. Bazavov (UC Riverside and U. of Iowa), D. Renner (Los Alamos), E. Gregory (Wuppertal U.), K. Orginos (William and Mary),

Short Curriculum Vitæ

Dr. Ubirajara VAN KOLCK
Department of Physics, University of Arizona, Tucson, AZ 85721
http://www.physics.arizona.edu/ vankolck/

Educational Background:

Ph.D., 1993 (Theoretical Physics)	University of Texas at Austin (S. Weinberg, advisor)
M.S., 1987 (Theoretical Physics)	Instituto de Física Teórica, São Paulo, Brazil
B.S., 1984 (Physics)	Universidade de São Paulo, São Paulo, Brazil

Professional Experience:

2012-date	Directeur de Recherche, Centre National de la Recherche Scientifique
2009-date	Professor of Physics, University of Arizona
2003-2009	Associate Professor of Physics, University of Arizona
2000-2003	Assistant Professor of Physics, University of Arizona
1998-2000	Senior Research Fellow, California Institute of Technology
1996-1997	Research Assistant Professor, University of Washington
1993-1996	Research Associate, University of Washington

Honorary and Visiting Appointments:

2013-date	Associated Partner, ExtreMe Matter Institute, GSI
2010-date	Affiliate Professor of Physics, Universidade Estadual Paulista
2002-date	Affiliate Assistant, Associate, Professor of Physics, University of Washington
2016	(Apr-May) Visiting Scholar, Institute for Nuclear Theory, Seattle
2010	(Apr-May) Visiting Scholar, Institute for Nuclear Theory, Seattle
2009	(Mar-June) Visiting Scholar, Institute for Nuclear Theory, Seattle
2007	(Jan-Aug) Visiting Professor, Instituto de Física Teórica, São Paulo
2006-2007	(Oct-Jan) Visiting Scientist, Kernfysisch Versneller Instituut, Groningen
2004-2013	Affiliate Member, Program in Applied Mathematics, University of Arizona
2004	(Sept-Nov) Visiting Scholar, Institute for Nuclear Theory, Seattle
2003	(Sept-Dec) Visiting Scholar, Institute for Nuclear Theory, Seattle
2000	(July-Aug) Visiting Scholar, Institute for Nuclear Theory, Seattle

Honors and Awards:

2015	Prix Paul Langevin, Société Française de Physique
2012-2016	Prime d'excellence scientifique, Centre National de la Recherche Scientifique
2009	Excellence in Graduate Physics Teaching Award, University of Arizona
2002-2006	Alfred P. Sloan Research Fellow, Alfred P. Sloan Foundation
2004	Fellow, American Physical Society
2001-2004	Outstanding Junior Investigator, US Department of Energy
2000-2004	RHIC Physics Fellow, RIKEN-BNL Research Center
1991-1993	Research Assistant to Prof. S. Weinberg, University of Texas at Austin
1987-1992	Doctorate Fellow, CNPq, Brazil
1985–1987	Master's Fellow, CAPES, Brazil
1983	Scientific Initiation Fellow, FAPESP, Brazil

Funding Awards (last five years):

2017-date	Senior participant, Key Project, NSF China
2014-date	Co-PI, research grant DE-FG02-04ER41338, DOE
2013-date	Senior participant, France-Brazil collaboration grants, CNRS
2014-2016	PI, France-China collaboration grant, CNRS

2012-2015	PI, Project grant, IN2P3, CNRS
2014	PI, France-China collaboration grant, Campus France
2013	PI, Research grant, Program Attractivité 2013, Université Paris-Sud
2010-2013	PI, research grant DE-FG02-04ER41338, DOE

Other Selected Research-Related Activities:

- Supervisor of 8 postdoctoral fellows, 9 Ph.D. students (2 current), 1 M.Sc. student, and 6 undergraduate students
- Organizer of 30 international conferences, workshops and advanced schools, and member of 19 conference advisory/program committees
- Member of various funding advisory committees such as the US Nuclear Science Advisory Committee (2006–2008)
- Reviewer of over 40 grant proposals/fellowship applications for Europe's ERC, Germany's DFG, Swiss NSF, Austria's ASF, US DOE, US NSF, US CRDF, Brazil's FAPESP, Canada's NSERC, and Guggenheim Foundation
- Editorial board member for *Phys. Rev. C* (2015-2017) and *Prog. Part. Nucl. Phys.* (2009-2013)
- Referee for over 160 articles in about 20 international journals and 5 book outlines for Cambridge UP and Oxford UP
- Member of institutional advisory committees, such as the US Institute for Nuclear Theory' National Advisory Committee, (2014-2017) and the European Centre for Theoretical Studies in Nuclear Physics and Related Areas' Scientific Board (2014-2018)
- Referee for promotion of 13 professors in American, Dutch and German universities and 7 faculty/staff search committees at American and French universities/laboratories
- Participant in several scientific society activities, such as Chair of the APS Topical Group on Few–Body Systems (2008–12)

Some Scientific Production Metrics:

- Published papers in peer-reviewed journals: 91
- Invited talks at international conferences and workshops: 115
- Proceedings contributions: 42
- Book chapters: 1
- Edited books and journal special issues: 4
- inSPIRE: 7,721 citations, 80.4 citations/paper, $h = 46$
- Web of Science: 6,711 citations, 58.4 citations/item, $h = 40$
- Google Scholar: 10,051 citations, $i10 = 84$, $h = 48$

Five Major Publications (Citations in inSPIRE):

1. P.F. Bedaque and U. van Kolck, "Effective Field Theory for Few–Nucleon Systems", *Ann. Rev. Nucl. Part. Sci.* **52** (2002) 339. (Citations: 529)
2. C. Ordóñez, L. Ray, and U. van Kolck, "The Two–Nucleon Potential from Chiral Lagrangians", *Phys. Rev. C* **53** (1996) 2086. (Citations: 520)
3. U. van Kolck, "Few–Nucleon Forces from Chiral Lagrangians", *Phys. Rev. C* **49** (1994) 2932. (Citations: 415)
4. P.F. Bedaque, H.-W. Hammer, and U. van Kolck, "Renormalization of the Three–Body System with Short–Range Interactions", *Phys. Rev. Lett.* **82** (1999) 463. (Citations: 352)
5. C. Ordóñez, L. Ray, and U. van Kolck, "Nucleon–Nucleon Potential from an Effective Chiral Lagrangian", *Phys. Rev. Lett.* **72** (1994) 1982. (Citations: 350)

Erich W. Varnes

The University of Arizona
Department of Physics
Tucson, AZ 85749
(520) 626-0217
varnes@physics.arizona.edu

EDUCATION

University of California, Berkeley, Ph.D. in Physics, 1997
Thesis title: *Measurement of the Top Quark Mass*
Advisor: Prof. Mark Strovink

University of California, Berkeley, M.A. in Physics, 1994

Johns Hopkins University, B.A. in Physics, 1992

EMPLOYMENT

2014 – Present:
Professor Department of Physics, University of Arizona

2008 – 2014:
Associate Professor Department of Physics, University of Arizona

2002 – 2008:
Assistant Professor Department of Physics, University of Arizona

1997 – 2002:
Robert H. Dicke Postdoctoral Fellow Department of Physics, Princeton University

1993 – 1997:
Graduate Research Assistant Department of Physics, University of California, Berkeley

KEY LEADERSHIP POSITIONS

2017-Present:
Background coordinator for the top quark physics group in ATLAS. ATLAS is one of two large multi-purpose experiments at the CERN Large Hadron Collider, consisting of about 3000 collaborating researchers.

2013-2016:
Physics Support Manager for US ATLAS. US ATLAS is the organization that coordinates the activities of the US-based collaborators on ATLAS (about 600 researchers).

2012-present:
Deputy Institutional Board Chair for the DØ experiment at Fermilab. DØ was one of the leading high-energy physics experiments, consisting of about 400 collaborating researchers at the time of appointment to this position. The experiment stopped taking data in 2011, but is still actively

producing physics results.

2007-2012:
Software Algorithms and Computing Coordinator for the DØ experiment at Fermilab.

2004-2006:
Leader of the top quark properties analysis group at DØ.

SELECTED PUBLICATIONS

I have authored over 900 peer-reviewed papers with the ATLAS, BaBar, and DØ collaborations. Those listed here are papers for which I was a primary author or made a significant contribution to the result presented.

1. "**Analysis of events with b-jets and a pair of leptons of the same charge in pp collisions at $\sqrt{3} = 8$ TeV with the ATLAS detector**", ATLAS Collaboration, JHEP **1709**, 084 (2015).
2. **"Search for the standard model Higgs boson in the $ZH \to \nu\nu bb$ channel in 9.5 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV"**, V. M. Abazov *et al.*, Phys. Lett. B. **716**, 285 (2012)
3. **"Measurement of the W Boson Helicity in Top Quark Decays using 5.4 fb$^{?1}$ of $p\bar{p}$ Collision Data"**, V. M. Abazov *et al.*, Phys. Rev. D **83**, 032009 (2011).
4. **"Measurement of the W Boson Helicity in Top Quark Decays at DØ"** V. M. Abazov *et al.*, Phys. Rev. D **75**, 031102(R) (2007); hep-ex/0609045; Fermilab-Pub-06/345-E.
5. "**Search for right-handed W bosons in top quark decay**", V. M. Abazov *et al.*, Phys. Rev. D Rap. Comm **72**, 011104 (R) (2005); hep-ex/0505031, Fermilab-Pub-05/187-E.
6. "**Measurement of branching fractions for exclusive B decays to charmonium final states**", B. Aubert *et al.*, Phys. Rev. D **65**, 032001 (2002); SLAC-PUB-8909; hep-ex/0107025.
7. "**The BaBar Detector**", B. Aubert *et al.*, Nucl. Instrum. Methods Phys. Res. A **479**, 1 (2002); SLAC-PUB-8569; hep-ex/0105044.
8. "**Observation of CP Violation in the B^0 system**" B. Aubert *et al.*, Phys. Rev. Lett. **87**, 091801 (2001); SLAC-PUB-8904; hep-ex/0107013.
9. "**Direct Measurement of the Top Quark Mass**", K. Tollefson and E.W. Varnes, in **Annual Review of Nuclear and Particle Science** (1999).
10. "**Measurement of the Top Quark Mass in the Dilepton Channel**", B. Abbott *et al.*, Phys. Rev. D **60**, 052001 (1999); Fermilab-Pub-98/261-E; hep-ex/9808029.
11. "**Electronics for the BaBar Central Drift Chamber**", J. Albert *et al.*, IEEE Trans. Nucl. Sci. **46**, 2027 (1998); SLAC-PUB-7996.
12. "**The BaBar Drift Chamber**", G. Sciolla *et al.*, Nucl. Instrum. Methods Phys. Res. A**419**, 310 (1998).
13. "**Measurement of the Top Quark Mass Using Dilepton Events**", B. Abbott *et al.*, Phys. Rev. Lett. **80**, 2063 (1998); Fermilab-Pub-97/172-E; hep-ex/9706014.

Curriculum Vitae ***Koen Visscher***

CHRONOLOGY OF EDUCATION

University of Amsterdam, The Netherlands, Ph.D., May 27 1993, Physics
Thesis: Optical Micromanipulation and Confocal Microscopy.
Advisor: Prof. J.T.M. Walraven; *Co–advisor*: Prof. G. J. Brakenhoff

University of Twente, The Netherlands, Msc.,May 1988, Applied/Technical Physics
Thesis: An investigation into the light scattering properties of white blood cells for differential cell–counting using a flow cytometer.
Advisor: Prof. Jan Greve

CHRONOLOGY OF EMPLOYMENT

Aug 2016 – *present*	Director of Research and Development, Inscopix Inc, Palo Alto, CA, USA (on 2-yr leave from the University of Arizona)
Aug 2004 – *present*	Associate Professor with Tenure, Dept. of Physics, University of Arizona, Tucson, AZ, USA.
	Associate Professor with Tenure, Dept. of Molecular and Cellular Biology (Joint Appointment).
	Member Graduate Interdisciplinary Degree Program (GIDP) in Applied Mathematics.
	Member, Bio5, Univ. of Arizona
April 2006 – *present*	Associate Professor with Tenure College of Optical Sciences (Joint Appointment since April 10, 2006)
June 2010	Visiting Professor, Institut d'Optique, Palaiseau, France.
May 2009 – Oct. 2009	Visiting Professor, Institut d'Optique, Palaiseau, France.
June 1999 – July 2004	Assistant Professor, Dept. of Physics, University of Arizona, Tucson, AZ, USA.
	Assistant Professor, Dept. of Molecular and Cellular Biology (Joint appointment).
	Affiliated Member Graduate Interdisciplinary Degree Program (GIDP) in Applied Mathematics.
June 1997 – May 1999	Scientific Staff Member of the Princeton Materials Institute with Prof. Steven M. Block, Princeton University, Princeton, NJ, USA (post–doc).
June 1994 – May 1997	Burroughs Wellcome Fund of the Life Sciences Research Foundation Fellow with Prof. Steven M. Block, Dept. of Molecular Biology, Princeton University, Princeton, NJ, USA (post–doc).
Feb. 1994 – May 1994	Research Associate with Prof. Steven M. Block, Dept. of Molecular Biology, Princeton University, Princeton, New Jersey, USA (post–doc).
June 1993 – Jan. 1994	Research Associate with Prof. R. Kraayenhof, Dept. of Molecular and Cellular Biology, Free University, Amsterdam, The Netherlands (Alternative Military/Social Service).
Aug. 1988 – May 1993	Graduate Research Associate (“promovendus”, in Dutch) in the laboratory of Prof. G.J. Brakenhoff, Dept. of Molecular Biology, University of Amsterdam, The Netherlands (“promovendus” is a full–time research position).

CONSULTANT
Inscopix, Palo Alto, CA, Jan.1 2015 – Aug. 2016

HONORS AND AWARDS

- Proceeding of the Royal Society A, top reviewer, 2011
- Visiting Professor, Institut d'Optique, Ecole Polytechnique, Palaiseau, France (May–Oct. 2009, June 2010).
- Joop Los Fellow, FOM Institute for Atomic and Molecular Physics (AMOLF, sabbatical), Amsterdam, 2007.
- Ehrenfest Colloquium, Leiden University, The Netherlands, Oct. 1, 2003.
- Arnold and Mabel Beckman Foundation, Beckman Young Investigator Award, 2001.
- Research Corporation, Research Innovation Award, 2000.
- Burroughs Wellcome Fund Fellow of the Life Sciences Research Foundation, 1994–1997.

SELECTED PUBLICATIONS

Visscher, K. Programmed Ribosomal Frameshifting as a force-dependent process, in *Progress in Molecular Biology and Translational Science* **139**, 45-72 (2016)

Bailey, B.L, Visscher, K., & Watkins, J. A stochastic model of translation with -1 programmed ribosomal frameshifting. *Phys. Biol*. 11, 016009 (2014).

White, K.H., Orzechowski, M., Fourmy, D. & Visscher, K. Mechanical unfolding of the Beet Western Yellow Virus -1 frameshift signal. *JACS* **133**¸9775-9782 (2011).

Skinner, G.M., Kalafut, B.S. & Visscher, K. Downstream DNA tension regulates the stability of the T7 RNA polymerase initiation complex. *Biophys. J.* **100**, 1034-1041 (2011).

Le Gall, A., Perronet, K., Dulin, D., Villing, A., Bouyer, P., Visscher, K., Westbrook, N. Simultaneous calibration of optical tweezers spring constant and position detector response. *Optics Express* **18**, 26469-26467 (2010).

Seol, Y, Stein, D.L. & Visscher, K. Phase measurements of barrier crossings in a periodically modulated double-well potential. *Phys. Rev. Lett.* **103**, 050601 (2009).

Seol, Y., Skinner, G.M., Buhot, A., Halperin, A., and Visscher, K. Stretching of homopolymeric RNA reveals single-stranded helices and base-stacking. *Phys Rev. Lett.* **98**, 158103 (2007)

Seol, Y., Walton, D.B, & Visscher, K. "Suppression of noise in a noisy optical trap" *Phys. Rev. Lett*. **93**, 160602 (2004).

Seol, Y., Skinner, G.M. & Visscher K., "Elastic properties of a single-stranded charged homopolymeric ribonucleotide". *Phys. Rev. Lett.* **93**, 118102 (2004).

Schnitzer M.J., Visscher K., and Block S.M., "Force production by single kinesin motors.", *Nature Cell Biology* **2**, 718-723 (2000)

Visscher K., Schnitzer M.J., and Block S.M., "Single kinesin molecules studied with a molecular force clamp." *Nature* **400**, 184-189 (1999). Featured in Nature Cell Biology News&Views: Knight A.E., and Molloy J.E., "Coupling ATP hydrolysis to mechanical work.", *Nature Cell Biology* **1**, E87-E89 (1999).

lecture)

Weigang Wang

1118 E 4th Street
Department of Physics
The University of Arizona
Tucson, AZ 85721
http://www.physics.arizona.edu/~wgwang

Office: 520-626-8846
Fax: 520-626-8801
Lab: 520-626-8827
Email: wgwang@physics.arizona.edu

Professional Preparation

- Minzu University of China, Beijing, China — Physics — B.S. 2001
- University of Delaware, Newark, DE, USA — Physics — Ph.D. 2008
- Johns Hopkins University, Baltimore, MD, USA — Physics — Postdoc, 2008-2012

Appointments

- **Assistant Professor** — Aug 2012-present
  Department of Physics, University of Arizona

Awards

- NSF CAREER Award, 2016
- Best Poster Award, 55th Conference on Magnetism and Magnetic Materials, 2010
- Professional Development Award, University of Delaware, 2007

Five Most Relevant Publications

1. T. Newhouse-Illige, Y. Liu, M. Xu, D. Reifsnyder Hickey, A. Kundu, H. Almasi, C. Bi, X. Wang, J. W. Freeland, D. J. Keavney, C. J. Sun, Y. H. Xu, M. Rosales, X. M. Cheng, S.F. Zhang, K. A. Mkhoyan, and W. G. Wang. "*Voltage controlled interlayer coupling in perpendicular magnetic tunnel junctions*". **Nature Communications**, 8, 15232 (2017)
2. Chong Bi, Meng Xu, Hamid Almasi, Macus Rosales and W. G. Wang, "*Metal Based Nonvolatile Field-effect Transistors*", **Adv. Funct. Mater**, 26, 3490 (2016).
3. Almasi, H., D. Reifsnyder Hickey, T. Newhouse-Illige, M. Xu, M. R. Rosales, S. Nahar, J. T. Held, K. A. Mkhoyan, and W. G. Wang. "*Enhanced tunneling magnetoresistance and perpendicular magnetic anisotropy in Mo/CoFeB/MgO magnetic tunnel junctions*." **Appl. Phys. Lett**. **106**, 182406 (2015):
4. C. Bi, Y. Liu, T. Newhouse-Illige, M. Xu, M. Rosale, J.W. Freeland, O. Mryasov, S. F. Zhang, S.G.E. te Velthuis, and W. G. Wang, "*Reversible control of Co magnetism by voltage induced oxidation*", **Phys. Rev. Lett**., **113**, 267202 (2014)
5. W. G Wang, M. E. Li, S. Hageman, and C. L. Chien *"Electric field assisted switching in magnetic tunnel junctions"* **Nature Materials**, **11**, 64 (2012)

Five Other Significant Publications

1. Chong Bi, Congli Sun, Meng Xu, Ty Newhouse-Illige, Paul M Voyles, W. G. Wang, "Electrical Control of Metallic Heavy-Metal-Ferromagnet Interfacial States", **Phys. Rev. Appl**., 8, 034003 (2017)
2. Chong Bi, Hamid Almasi, Kyle Price, Ty Newhouse-Illige, Meng Xu, Shane Allen, Xin Fan and W. G. Wang, "*Anomalous spin-orbit torque switching in synthetic antiferromagnets*", **Phys. Rev. B**. 95, 104434 (2017)
3. H. Almasi, M. Xu, Y. Xu, T. Newhouse-Illige, and W. G. Wang, "*Effect of Mo insertion layers on the magnetoresistance and perpendicular magnetic anisotropy in Ta/CoFeB/MgO junctions*". **Appl. Phys. Lett**. 109, 032401 (2016).
4. H. Almasi, M. Xu, Y. Xu, T. Newhouse-Illige, and *W. G. Wang*, "*Effect of Mo insertion layers on the magnetoresistance and perpendicular magnetic anisotropy in Ta/CoFeB/MgO junctions*". **Appl. Phys. Lett.** 109, 032401 (2016).
5. S. Y. Huang, W. G. Wang, S. F. Lee, J. Kwo, and C. L. Chien, *"Intrinsic spin-dependent thermal transport"* **Phys. Rev. Lett**., **107**, 216604 (2011)

Synergistic Activities

- **Referee** for over 25 journals such as Nature Series, PNAS, Physical Review Series, Applied Physics Letters, IEEE Transactions on Magnetics, Advanced Materials, *et. al.*
- **Program Committee Member**:
  - *62nd Annual Conference on Magnetism and Magnetic Materials (2017)*
  - *61st Annual Conference on Magnetism and Magnetic Materials (2016)*
- **Conference Session Chair**
  - *Topological Insulator/Ferromagnet Heterostructures for Spintronics*, 61st annual MMM conference, 2016, New Orleans
  - *Spin-Orbit Effects*, 2015 APS March Meeting, March 2015, San Antonio, TX
  - *Magnetization Dynamics*, 59th Annual MMM Conference, Nov. 2014, Hawaii
  - *Magnetic Anisotropy*, 2014 APS March Meeting, March 2014, Denver, CO
  - *Spin Pumping*, 58th MMM Conference, Nov. 2013, Denver, CO
  - *Resistive Switching*, 13th Non-Volatile Memory Symposium, August 2013 , Minneapolis, MN
  - *Biomagnetics and Magneto-Optics Effects*, 2013 APS March Meeting, March 2013, Baltimore, MD
  - *Magnetic Tunnel Junction*, 2012 Intermag Conference, May 2012, Vancouver, Canada
- **Poster judging panel**, 2012 IUMRS-ICYRAM conference
- **Mentor**, Women in Science and Engineering (WISE) program

Charles W. Wolgemuth

1.1 Professional Preparation

Undergraduate, Graduate and Postdoctoral Training

University of Arizona, AZ	Physics	B.Sc.	1995
University of Arizona, AZ	Physics	M.S.	1996
University of Arizona, AZ	Physics	Ph.D.	2000
University of California, Berkley, CA	Molecular and Cellular Biology	2000-2002	

1.2 Appointments

Aug. 2016 – present Professor of Physics and Molecular and Cellular Biology, University of Arizona with adjunct appointment in the Department of Cell Biology at the University of Connecticut Health Center.

Aug. 2012 – 2016 Associate Professor of Physics and Molecular and Cellular Biology, University of Arizona with adjunct appointment in the Department of Cell Biology at the University of Connecticut Health Center.

Sept. 2008 – July 2012 Associate Professor of Cell Biology (with adjunct appointments in Physics and Biomedical Engineering), University of Connecticut Health Center

Aug. 2002 – Sept.2008 Assistant Professor of Cell Biology, University of Connecticut Health Center

1.3 Publications

1.3.1 Publications Most Closely Related to This Proposal

[1] M. Zajac and C.W. Wolgemuth. 2010. The moving boundary node method: a level-set based, finite volume algorithm with applications to cell motility. J. Comput. Phys. **229**: 7287-7308.

[2] P. Lee and C.W. Wolgemuth. 2011. Crawling cells can close wounds without purse strings or signaling. PLoS Comput. Biol. **7**: e1002007.

[3] P. Lee and C.W. Wolgemuth. 2011. Advent of complex flows in epithelial tissues. Phys. Rev. E **83**: 061920.

[4] P. Lee and C.W. Wolgemuth. 2016. Physical mechanisms of cancer in the transition to metastasis. Biophys. J. **111**: 256-266.

[5] D.K. Vig, A.E. Hamby, and C.W. Wolgemuth. 2017. Cellular contraction can drive rapid epithelial flows. Biophys. J. (in press)

1.3.2 Other Significant Publications

[6] C.W. Wolgemuth. 2008. Collective swimming and the dynamics of bacterial turbulence. Biophys. J. **95**: 1564-1574.

[7] C.W. Wolgemuth, J. Stajic, and A. Mogilner. 2011. Redundant mechanisms for stable cell locomotion revealed by minimal models. Biophys. J. **101**: 545-553.

[8] T. Fuhs, M. Goegler, C.A. Brunner, C.W. Wolgemuth and J.A. Kaes. 2014. Causes of retrograde flow in fish keratocytes. Cytoskeleton. **71**: 24-35.

[9] P. Lee and C.W. Wolgemuth. 2016. An immersed boundary method for two-phase fluids and gels and the swimming of *Caenorhabditis elegans*. Phys. Fluids. **28**: 011901.

[10] M.W. Harman, A.E. Hamby, R. Boltyanskiy, A.A. Belperron, L.K. Bockenstedt, H. Kress, E.R. Dufresne, and C.W. Wolgemuth. 2017. Vancomycin reduces cell wall stiffness and slows swim speed of the Lyme disease bacterium. Biophys. J. **112**: 746-754.

1.4 Synergistic Activities

Conference Organizer, From motors to morphogenesis: Oster-inspired research (2009)
Editorial Board Member, Biophysical Journal (2010-2016)
Editorial Board Member, Mathematical Medicine and Biology (2015-present)
Editorial Board Member, Letters in Biomathematics (2015-present)

Biographical Sketch

Shufeng Zhang

Address:

Physics Department, University of Arizona, Tucson, AZ 85721
Phone: 520-621-6835; Fax: 520-621-4721, email: zhangshu@email.arizona.edu

Education:

B.S. in Physics	1985, University of Science and Technology of China
Ph.D. in Physics	1991, New York University (advisor: Peter M. Levy)
Postdoc.	1991-1992, University of California-San Diego

Professional Experience:

2008-present	University of Arizona, Professor
2005-2008	University of Missouri, Professor
2002-2005	University of Missouri, Associate Professor
1998-2002	University of Missouri, Assistant Professor
1993-1997	New York University, Research Assistant Professor
1992-1993	Hewlett Packard Laboratories, Research Scientist

Awards:

Outstanding Dissertation Award of New York University, 1991
Hewlett-Packard Visiting Faculty Fellowship, 1992-3
Oversea Chinese Outstanding Young Scholar, 2005
Elected Fellow, American Physical Society, 2005
Henry and Phyllis Koffler Prize, University of Arizona, 2017

Recent Synergistic Activities

Advisory board member, J. Magn. Magn. Mater., (2015-).
Elected executive member (member-at-large) of the GMAG group, APS (2010-2013).
External advisory board member, DOE Energy Frontier Center, UC Riverside (2015-)
Editorial review board member of IEEE Magnetic Transaction Letter (2009-).

Five Most Related Publications

1. T. Newhouse-Illige, Y. Liu, M. Xu, D. R. Hickey, A. Kundu, H. Almasi, Chong Bi, X. Wang, J. W. Freeland, D. J. Keavney, C. J. Sun, Y. H. Xu, M. Rosales, X. M. Cheng, Shufeng Zhang, K. A. Mkhoyan, and W. G. Wang, *Voltage-controlled interlayer coupling in perpendicularly magnetized magnetic tunnel junctions*, Nature Comm. **8**, 15232 (2017).

2. Kai Chen, Weiwei Lin, C. L. Chien, and Shufeng Zhang, *Temperature dependence of angular momentum transport across interfaces*, Phys. Rev. B 94, 054413 (2016).

3. Weiei Lin, Kai Chen, S. Zhang, and C. L. Chien, *Enhancement of Thermally Injected Spin Current through an Antiferromagnetic Insulator*, Phys. Rev. Lett. **116**, 186601 (2016).

4. S. S. -L. Zhang and S. Zhang, *Magnon Mediated Electric Current Drag Across a Ferromagnetic Insulator Layer*, Phys. Rev. Lett. **109**, 096603 (2012).

5. Kai Chen and Shufeng Zhang, *Spin Pumping in the Presence of Spin-Orbit Coupling*, Phys. Rev. Lett. **114**, 126602 (2015).

Five other publications

1. Shufeng Zhang and Albert Fert, *Conversion between spin and charge currents with topological insulators*, Phys. Rev. B**94**, 184423 (2016).

2. J. Li, Y. Xu, M. Aldosary, C. Tang, Z. Lin,1 Shufeng Zhang, R. Lake, and J. Shi, *Observation of magnon-mediated current drag in Pt/yttrium iron garnet/Pt(Ta) trilayers*, Nature Comm. **7**, 10858 (2016).

3. A. Kundu and S. Zhang, *Dzyaloshinskii-Moriya interaction mediated by spin-polarized band with Rashba spin-orbit coupling*, Phys. Rev. B 92, 094434 (2016).

4. S. Zhang and Z. Li, *Roles of non-equilibrium conduction electrons on ferromagnets*, Phys. Rev. Lett. **92**, 127204 (2004).

5. S. Zhang and S. S.-L. Zhang, *Generalization of the Landau-Lifshitz-Gilbert equation for conducting ferromagnets*, Phys. Rev. Lett. **102**, 086601 (2009).

A complete list of publications can be found at https://scholar.google.com, search for Shufeng Zhang.

E Committees

Committee assignments 2017-2018

Executive: Mazumdar, Johns, Sandhu, Varnes, Wolgemuth, van Kolck.

CAPE: Zhang (Chair), Rutherfoord, TBE.

P&T -Toussaint (joint chair), Stafford (joint chair), Sarcevic, Lebed, ?.

Space - LeRoy, Melia, Beck, Lebed, Eklund.

Grad Committees

Director of Graduate Studies: Fleming.

Grad Advisors: Fleming, Sarcevic, Lueders.

Grad Admissions: Fleming, Lebed, Hassan, Wang, Rozo, Schaibley, Zhang

Grad Recruitment: Fleming, Sandhu, Su.

Grad Curriculum: Su, Schaibley, Gralla, Fleming.

Examinations: Meinel (Chair, Fall), Wolgemuth (Chair, Spring), Gralla, Zhang, Toussaint (Fall), Wang (Spring).

Undergrad Committees

DUGS: Milsom

Lab Reform: LeRoy, Singh.

Curriculum: Johns, Cheu, Milsom, Manne, Schaibley, Rozo.

Arts and Science Advisors: Milsom, Holly Brown, Varnes, LeRoy.

Teaching Evaluation and Innovation. Johns, Milsom, Manne, Sandhu, Rozo, Fleming, Singh (for TAs)

Recruitment: Manne, Jackson, Mazumdar, Johns, Gralla, Schaibley.

Other Committees:

Student nonacademic job opportunities: Mazumdar, Johns, Zhang, Varnes, Wang.

Awards - Faculty and Staff: Su, Lebed, Sarcevic, Carmen Montijo

Awards - Students: Wolgemuth, Jackson, Stafford.

Staff performance evaluation. Rutherfoord, Mazumdar.

PR and Outreach: Johns, Mazumdar, Manne, Jackson, Rozo, Alexis Cibrian

Colloquium - Rozo (Chair, Fall), Meinel (Chair, Spring), Melia, Sandhu, Wang.

Gender equity and diversity - Rozo, Su, van Kolck.

Staff Machine Shop: Schaibley, LeRoy, Sandhu, Wang.

APR Committee: Johns, Varnes, Cheu, Stafford, Sarcevic, Wolgemuth, van Kolck.

F Academic Advisor Duties

University of Arizona
Department of Physics
Undergraduate Advising Summary
1/31/18

Holly Brown is the Senior Academic Advisor I for the Department of Physics (as well as the Department of Astronomy). This full-time advising position was created in conjunction with the College of Science in March 2016. Prior to this, faculty advisors had served this function on a part-time basis for students. Ms. Brown oversees 239 physics majors and 31 minors, with approximately 100 new students coming in to the major each year. Advisor duties encompass student needs from prospective students/orientation until graduation. Duties include hosting prospective students and families for informational visits, coordinating summer and spring orientation for approximately 100 students per year, assisting students with all needs relating to degree requirements and planning, registration, finding and signing up for required research units, preparing for and finding internships and research, preparing for graduate school, probation and retention efforts, department scholarship application management, student data collection and evaluation, website maintenance, graduation steps, and any other ongoing student needs. In the Department, students have mandatory advising meetings every semester until the end of their sophomore year, and a following mandatory meeting to complete graduation paperwork in their senior year. Advisor typically maintains nine hours of walk-in advising per week and six to ten hours of advising appointments which students can schedule online.

Some highlights of recent accomplishments in advising:

- Co-host biweekly workshops through the Tucson Initiative for Minority Engagement in Science and Technology Program (TIMESTEP) in conjunction with faculty from Astronomy and Physics. These regular Wednesday workshops are designed for underrepresented minorities in the sciences but are open to all students, and regularly see 20-30 students per session. Workshops are geared to be hands-on with instruction from current students, grad students and post docs on practical steps to be successful in each degree program. Workshop topics in the past have included Getting Involved in Research, Graduate School Applications and Statement Reviews, Imposter Syndrome, Job Searching, Resumes and LinkedIn, and more.
- Creation of a Careers & Internships page on the website with a large variety of resources for students not pursuing graduate school, including statistics on employment from American Institute of Physics, career planner tools, job and internship boards, and job seeker resources.
- Through College of Science, teach a Student Success Course every spring semester for students on probation (or students looking to improve their academic skills). SCI 195A encompasses topics on learning how to learn and the neuroscience of learning, university policies and procedures, degree and career planning, and setting achievable goals for the semester and students' academic careers.
- Coordinate a student Town Hall every year when current students can meet with the Department Head, Associate Head, Director of Undergraduate Advising and the Senior Academic Advisor to share feedback about the department, courses, and make suggestions moving forward.
- Currently completing a database of national scholarships for Physics and STEM majors for additional funding, to be made available to students later in the Spring 2018 semester.
- Represent the department for recruitment at the Meet Your Major Fair every fall semester.

G PHYS 200 Syllabus

Physics 200: The Science of Good Cooking (Spring 2017)

Instructors: Srinivas Manne (lead), Charles Wolgemuth (guest)
Office PAS 569 or 575 ; Phone 626-5305 ; E-mail smanne@email.arizona.edu
Office hours: TTh 10 – 11 am and 12:15 – 1:15 pm and by appointment
Assistants: Madi Egan (preceptor), Ian Harley-Trochimczyk (grader, iharleyt@email.arizona.edu)

Overview

This course shows students how to cook well using scientific observation, experiment and hypothesis testing. Lectures introduce the conceptual physics and chemistry behind kitchen technology and the cooking process, including heat transfer, phase transformations, and material properties of foods. Students perform kitchen experiments at home using guidelines provided in class and turn in reports of their observations. Semester grades are based on six reports, two midterm exams, lab notebook and occasional quizzes.

Prerequisites

There are no mandatory prerequisites, but students should be familiar with high-school level algebra and very basic chemistry.

Textbook

The required text for this course is *The Science of Good Cooking* by the Editors of America's Test Kitchen and Guy Crosby Ph.D. Other good references (not required) include *On Food and Cooking: The Science and Lore of the Kitchen* by Harold McGee, and *Molecular Gastronomy* by Herve This. Fair-use excerpts and supplementary notes will be posted on D2L as necessary. Students must also purchase a lab notebook with bound, numbered pages (see below).

Lectures, Attendance and In-class Quizzes (5% of your grade)

Students are expected to attend every lecture and will be responsible for all material covered and announcements made during the lecture. Lectures will be a combination of formal instruction, discussion, demonstration, and experimentation. I will also try to arrange one or two guest lectures from master chefs and bakers who apply scientific principles to cooking.

The reading assignment for a given date will be posted a few days ahead of time, and occasional short quizzes will be given in class (about 10 throughout the semester) to encourage attendance and advance reading. The net quiz score will be worth 5% of your grade.

Cooking Project Reports (60% of your grade)

Taking a scientific approach, students will keep a lab notebook or diary of their cooking experiments and communicate their results with project reports (3 to 5 pages). There will be six reports submitted during the semester, each worth 10% of the student's grade. <u>Each report must be submitted with relevant notebook pages attached as a single pdf file</u>. The first one or two cooking projects will be common to all students and will come with detailed instructions and questions for students to answer. The remaining projects may be chosen by each student according to their own interests, as long as they cover a broad range of cooking.

Student projects must use only non-specialized equipment and materials commonly found in kitchens and grocery stores. Each project must be an *experiment*, where the student explores a specific question and makes detailed measurements to try to answer the question. In each report, students will describe the purpose of the cooking experiment, materials and lab procedure, controls and experimental variables, results, and their recommendations for future students attempting the same project. Each project should involve observations and measurements (e.g. weight, temperature, consistency, color) before, after, and (if possible) during cooking. The report should analyze these data to form a plausible explanation of how the cooking process worked.

Reports will be graded on grammar and writing style (clear, concise, no-frills) as well as scientific content. Each report (with attached notebook pages) will be hand-graded using a 10-point maximum. Each report MUST include small photos (or link to video) of the project or dish at various stages of preparation, as well as at least one selfie with the project. A typical report might be 2-3 pages of single-spaced text and 1-2 pages of images, data tables and graphs. During the cooking project, students may work alone or in groups of two (no more!), but each student must turn in their own original report. All submitted reports will be auto-checked for plagiarism.

<u>Lab Notebook (5% of your grade)</u>

The bound lab notebook will serve as a single continuous diary of student projects through the course of the semester. Its purpose is "self-communication," so formal sentences and obsessive neatness are not necessary. However, the diary function must be strictly maintained. Students must write in pen, date the top of every page, and must never tear out or reorder any of the pages. When turning in a project report, students will copy and attach the relevant pages from the notebook to the report. The complete notebook itself will be turned in at the end of the semester. (Students can pick it up from the instructor, if they wish, after grades have been submitted.)

The notebook grade will depend on two factors: (1) adherence to the diary function, and (2) breadth of cooking projects chosen during the semester. Students are expected to choose projects covering most of the techniques discussed during the semester, e.g., frying, boiling, roasting/grilling, baking bread, preserving, fermenting, infusion/extraction etc.

<u>Exams (30% of your grade)</u>

There will be two exams, each worth 15% of the student's grade. Exam questions will be essay and short-answer, sometimes with simple calculations. Students are allowed a single 8.5 x 11 memory sheet (both sides), on which they may write or print whatever they choose. The 2^{nd} exam will be given at the official date and time of the final exam, although it will not be comprehensive and will mostly cover the material from the latter half of the course.

The best way to do well in quizzes and exams is to take good notes in lecture and on the reading. Study these notes, along with supplementary material and study guides posted on D2L, and pay special attention to terms, concepts and definitions.

Grading

Each student's total score for the course will be determined from the weighted average described above. In summary, project reports will count toward 60% of the grade (6 reports at 10% each), exams will count toward 30% (2 exams at 15% each), and quizzes and lab notebook will each count toward 5% of the course grade. Out of this maximum of 100%, letter grades will be assigned on a fixed scale as follows:

(A) 85%-100% (B) 75%-85% (C) 65%-75% (D) 55%-65% (E) <55%

Incompletes will only be given to students who have satisfactorily completed the majority of the course work and have *serious* reasons for not completing the rest.

Sample calculation: If a student averages 86% on the reports, gets 78% and 82% on the two exams, 63% on quizzes and 100% on the lab notebook, their net course score is:

[0.6 * 86] + [0.15 * (78 + 82)] + [0.05 * 63] + [0.05 * 100] = 83.75%, which is a B.

Honors Students

Students who take this course for Honors credit will substitute one of the six cooking experiments with a more complex, multi-variable project chosen in collaboration with the instructor. The results of this project will be given as a short presentation in front of the class.

University Policies

Excused Absences: All holidays or special events observed by organized religions will be honored for those students who show affiliation with that particular religion. Absences pre-approved by the UA Dean of Students (or Dean's designee) will be honored.

Accommodation for Student Disabilities: We will coordinate with the Disability Resource Center (DRC) and make all reasonable accommodations for student disabilities.

Academic Integrity: The university code of academic integrity will be strictly enforced in this course (see http://deanofstudents.arizona.edu/academicintegrity). Students are expected to do their own experiments (with at most one partner) and turn in their own writing.

Threatening Behavior will not be tolerated, and university procedures on such behavior will be strictly followed (see http://policy.web.arizona.edu/threatening-behavior-students).

Sample List of Subjects and Topics for Lecture

The lectures introduce and build on the conceptual foundations of mechanics, electromagnetism, heat flow, phase changes, materials properties and biochemistry, by applying these ideas to cooking and preservation of foods. This list of sample topics is not intended to be comprehensive (and not everything on this list will be covered), but it is representative of the breadth and scope of this course.

1. Fundamentals of food safety and the history of cooking
2. Fundamentals of measurement, weights vs. volumes

3. Heating techniques and related physics: Open flame, pressure, electric, solar, induction, microwave, infrared, isothermal cooking (double boiler)
4. Molecular building blocks of food: Hydrophilic vs. hydrophobic, sugars, starches, proteins, fats, inorganics, how to read food labels.
5. Food preservation chemistry: Brining, pickling, jamming, freezing, fermentation
6. Material properties of foods: Solids, liquids, gases, foams, gels, viscous properties
7. Cooking gear and how to choose their physical properties: Ceramics vs. metals, pyrex vs. glass, clay pots, nonstick surfaces, magnetic materials for inductive cooking
8. Temperature distributions and variations: Regular vs. fan ovens, "flour test" for uneven heating in pots and pans, physics of heat flow
9. Beverages as multiphase liquids: Carbonation, steam espressos, milk foaming, how to decaffeinate coffee, metastable liquids
10. Emulsions: Colloids and colloidal stabilization in mayonnaise, milk, cream
11. Physics and chemistry of phase changes: Making ice cream, making whipped cream, making butter and meringue, caramelization, protein denaturation
12. Physiological aspects of cooking and eating: Origins of smell and taste, mouthfeel, texture, color perception and iridescence, al dente cooking
13. Cooking with water: Boiling, simmering, pre-boiling, high vs. low altitude cooking, hot spring eggs, sous vide cooking
14. Grilling meat: Chemical changes in searing vs. slow cooking, smoking vs. flaming, penetration of marinade
15. Cooking with oil: Flash points and denaturation temperatures of oils, frying vs. stir-frying vs. deep-frying, deliberate charring
16. Steam and pressure cooking: Why is it faster and hotter? Avoiding the mechanical agitation of boiling
17. Chemistry of fibrous vegetables and tubers: Differences from meat fibers require different techniques of cooking
18. Physics and chemistry of baking: Structure of yeast, how to knead dough and why, what happens to bread when it rises, how to prevent collapse, physics and chemistry of other baked goods such as flan, cookies, pastries and souffles
19. Fancy desserts: Pressure extrusion of chocolate and cotton candy, structure of mousse and meringue, controlling heat transfer in baked Alaska
20. Popcorn and pressure vessels: Yield stress of seedpods, conversion of starch to liquid and steam, sudden adiabatic cooling, what other seeds can be popped?
21. Large-scale and industrial food production: Economies of scale, heating techniques for large volumes, local vs. transportable food, chemistry of industrial preservatives

H B.S. Requirements

Requirements for the BS in physics

General education requirements

Foreign language to second semester level
English Composition [placement by English Department]
General Education study areas other than science (science & math are automatically satisfied)
* [See the College of Science advising staff (Gould-Simpson 1017) for details]
* Tier 1: four courses (2 TRAD & 2 INDV)
* Tier 2: four courses (ART, HUM, INDV, DIVERSITY) The Diversity requirement can be a course which also satisfies one of the other three (so usually only three are needed).

Physics requirements

Our introductory sequence:
Physics 161H, 162H, 261H, 263H   (141, 142, 241 can replace the first three courses if approved by your advisor)
PHYS 105A (Introduction to Scientific Computing)
PHYS 204 (Mathematical Techniques in Physics)
PHYS 305 (Computational physics)
PHYS 321 (Classical Mechanics I)
PHYS 331 (Electricity and magnetism I)
PHYS 332 (Electricity and magnetism II)
PHYS 371 (Quantum Theory I)
PHYS 381, 382 (Methods in Experimental Physics I and II)
PHYS 426 (Thermal and Statistical Physics)
PHYS 472 (Quantum Theory II)

Six units chosen from:
Physics 320 (optics), 405 (digital electronics), 422 (classical mechanics II), 431 (biophysics), ATMO 436A (atmospheric science), 450 (nuclear and particle physics), 460 (solid state physics), 468 (classical and quantum relativity), 469 (general relativity), 473 (spectroscopy), 476 (mathematical methods), and 483 (advanced lab III)

Research requirement:
Three units chosen from Physics 483 (advanced lab project), 492 (directed research), 498 (senior capstone). **NOTE**: 483 cannot simultaneously count for this and the six unit requirement directly above.

Math prerequisites for required physics courses

MATH 124 or 125 (Calculus I)
MATH 129 (Calculus II)
MATH 223 (Vector calculus)
MATH 254 (Differential equations)

I B.A. Requirements

Requirements for the BA in physics

General education requirements

Foreign language: 4 semesters required
English Composition [placement by English Department]
General Education study areas other than science (science & math automatically satisfied)
[See the College of Science advising staff (Gould-Simpson 1017) for details]
Tier 1: four courses (2 TRAD & 2 INDV)
Tier 2: four courses (ART, HUM, INDV, DIVERSITY) The Diversity requirement can be a course which will satisfy one of the other three; so usually only three are needed.

Physics requirements

One of the introductory sequences:
I. Physics 161H, 162H, 261H, 263H
II. Physics 141, 142, 241, 263H
Although not recommended, the sequence:
III. 102, 103, 181, 182, 263H will be accepted under special circumstances.
PHYS 305 (Computational physics)
PHYS 321 (Mechanics I)
PHYS 331 (Electricity and magnetism I)
PHYS 371 (Quantum Theory I)
PHYS 381, 382 (Advanced Lab I and II)

Six units of additional upper-division physics courses

A minor is not required for the BA degree

Math prerequisites for required physics courses

MATH 124 or 125 (Calculus I)
MATH 129 (Calculus II)
MATH 223 (Vector calculus)
MATH 254 (Differential equations)

J Proposed B.S. in Applied Physics Degree Requirements

NEW ACADEMIC PROGRAM – PLANNING REQUEST

I. PROGRAM NAME, CIP CODE, AND ACADEMIC HOME

A. PROPOSED PROGRAM NAME AND DEGREE(S) TO BE OFFERED

BS in Applied Physics. Students will complete a Bachelor of Science degree in Applied Physics.

B. CIP CODE – 14.1201, Engineering Physics / Applied Physics

C. DEPARTMENT/UNIT AND COLLEGE – Physics Department, College of Science

II. PURPOSE AND NATURE OF PROGRAM

A. PROVIDE A BRIEF DESCRIPTION/JUSTIFICATION OF NO MORE THAN 100 WORDS FOR THIS PROGRAM

We propose a new major in Applied Physics to complement our existing major in Physics. The new major will emphasize applications of physics in technology and in complex real-world problems outside the scope of the traditional major. Students in Applied Physics will be trained in statistics, scientific communication and team-based problem solving with team members from other disciplines. We anticipate that this training will better prepare students for post-Bachelor's careers in the private sector and in public policy.

B. LIST THE TARGET CAREERS FOR STUDENTS ENROLLED IN THIS PROGRAM.

Many physics departments at major research universities now offer two separate degrees consistent with the current proposal: a degree in comprehensive or general physics (aimed at students interested in advanced degrees in physics) and a degree in applied or engineering physics, aimed at students interested in private-sector or civil service jobs after their BS. The proposed Applied Physics major is designed to serve undergraduates intending to (a) enter the workforce in the engineering, information technology or financial sector, or (b) obtain advanced degrees in a related field such as engineering, chemistry or medicine, or (c) obtain government or advising positions in science and public policy. This group will be distinct from traditional Physics majors. Although there is a substantial overlap in required coursework, Applied Physics majors will replace 18 units of upper-division physics coursework with a combination of required courses in statistics and scientific communication, technical electives focused on the student's career interests, and a year-long engineering design project (ENGR 498A and 498B), working with a mixed group of students from other science and engineering fields.

C. LIST THE PROJECTED STUDENT ENROLLMENTS FOR THIS PROGRAM.

We anticipate that initially, the majority of undergraduates choosing the new major will shift over from our existing Physics major. However, we anticipate an overall doubling of the total Physics/Applied Physics majors by year 5 due to the addition of the new major. This is

consistent with the results of a similar program at Rutgers University, highlighted in the "Best Practices" sites of the American Physical Society:
https://www.aps.org/careers/guidance/advisors/bestpractices/bestpractice-2a.cfm

Upon approval, the department plans a strong push to promote the Applied Physics major, especially to large local high schools and to prospective transfer students from Pima Community College. Our target student enrollees are those who enjoy physics but do not have long-range plans for academic careers in physics and are reluctant to pursue a major perceived as "impractical" for a career. Our experience with REU programs and minority-student conferences such as SACNAS has shown that this attitude is particularly prevalent among under-represented minorities. We anticipate that a side-benefit of the Applied Physics major will be the recruitment and retention of under-represented minorities in the department.

III. PROGRAM REQUIREMENTS

A. CORE COURSES

The total number credits required for completion of the major is 59.

Applied Physics, Introductory course requirements. During the first two years, students must complete 19 units of coursework in physics, listed below.

Phys 105A (1 unit), Introduction to Scientific Computing
Phys 161H (4 units), Introduction to Mechanics
Phys 162H (4 units), Introduction to Thermodynamics, Optics and Waves
Phys 261H (4 units), Introduction to Electricity and Magnetism
Phys 263H (3 units), Introduction to Modern Physics
Phys 204 (3 units), Mathematical Methods in Physics

Applied Physics, Upper-division course requirements. Upon successful completion of the 19 units listed above, applied physics majors will meet with faculty advisors to plan an upper-division course package that best suits their post-baccalaureate plans. Students will complete an additional 40 units of required course work and project experience, listed below.

Required Physics courses (16 units):

Phys 305 (3 units), Computational Physics
Phys 321 (3 units), Theoretical Mechanics I
Phys 331 (3 units), Electricity & Magnetism I
Phys 371 (3 units), Quantum Mechanics
Phys 381 (2 units), Methods in Experimental Physics I
Phys 382 (2 units), Methods in Experimental Physics II

Communication course (3 units):

One course from the following: COMM 119 (Public Speaking), ENGL 308 (Scientific and technical communication), ENGL 340 (Topics in professional and technical writing), JOUR 472 (Science journalism), or JOUR 455 (Environmental journalism). This requirement can also be satisfied by a similar communication course approved by an advisor.

Data analysis/statistics/modeling (3 units):

One course from the following: ISTA 311 (Foundation of information and inference), ISTA 321 (Data mining and discovery), ISTA 350 (Programming for informatics), ISTA 410 (Bayesian modeling and inference), ISTA 421 (Introduction to machine learning), or MATH 263 (Introduction to statistics and biostatistics). This requirement can also be satisfied by a similar data analysis/statistics/modeling course or independent study approved by an advisor.

Focused technical electives (12 units, at least 6 of which must be upper division):

These will be chosen in close consultation with a faculty advisor and selected to complement the student's post-baccalaureate career interests. These could be applied courses in biology, physical chemistry, physics, computer science, optics, or various engineering departments. Of these courses, 6 units can be lower-division (to satisfy prerequisites), but at least 6 must be upper-division.

Senior engineering design project (6 units):

Engr 498A and Engr 498B. Students work in cross-disciplinary teams of four or five on projects funded by industry. We have received approval from the Engineering college for participation of Applied Physics students (anticipated rate 5-10 seniors participating per year). This requirement can also be satisfied by 6 units of Phys 493 (Internship), in the event that an equivalent team experience can be found in the private sector.

Comparison with existing Physics major:

Applied Physics drops the following course requirements (18 units) from the existing physics major: Phys 332, Phys 426, Phys 472, two upper-division physics electives, and the research capstone course (Phys 483 or 498). These are replaced with the following requirements: communication course (3 units), data analysis course (3 units), focused technical electives (12 units), and the design project (6 units).

B. NEW COURSES NEEDED

No new course development is anticipated.

C. LOCATION AND METHOD OF DELIVERY

All courses will be provided in-person as part of the Main Campus Program.

V. STUDENT LEARNING OUTCOMES – list 4-5 student learning outcomes for this program.

Learning objectives for the Applied Physics major emphasize depth of scientific knowledge of the field and the application of this knowledge to address technological problems.

1. Applied Physics majors will demonstrate core knowledge of the theories that form the basis of classical mechanics, electromagnetism, quantum mechanics, optics, and thermodynamics.
2. Applied Physics majors will demonstrate the ability to design and conduct experiments to investigate physical phenomena. They will show the ability to document, analyze, interpret and communicate the results of these experiments in written and oral form.

3. Applied Physics majors will demonstrate proficiency in using mathematical or computational skills to investigate physical phenomena or to optimize solutions to technological problems.
4. Applied Physics students will demonstrate the ability to work in multidisciplinary teams to address technological problems arising in academic, government or private sectors.
5. Applied Physics graduates will show appropriate preparation to assume challenging technical positions in a variety of industries, or to continue further study in technical fields such as engineering, medicine, data science, technical law, education and management.

VI. EXPECTED FACULTY PARTICIPATION

A. CURRENT FACULTY

All physics courses will be taught by current physics faculty.

B. ADDITIONAL FACULTY

We do not anticipate the need for additional faculty solely for the applied physics major. However, we will require **one additional teaching assistant** to teach extra lab sections in the introductory courses.

VII. FINANCING

A. LIST THE SOURCE OF FUNDS TO INITIATE THE PROGRAM.

Additional funds are not anticipated at this time.

B. PLEASE INDICATE IF A PROGRAM FEE OR DIFFERENTIAL TUITION WILL BE REQUESTED FOR THIS PROGRAM. Note that your request to ABOR for a new program with a program fee/differential tuition requires submission of the form ABOR Request to Establish a New Academic Program Requiring a Program fee at http://www.academicaffairs.arizona.edu/program-fees.

K PHYS 382 Creative Project

Independent project evaluation criteria

* Proposal (10pts)
* Progress reports (2-3x) (10pts)
* Construction of apparatus (30pts)
* Lab notebook (50pts)
  - Equipment list
  - Design diagrams
  - Detailed chronological log of progress
  - Theory / Working equation
  - Data
  - Data analysis
  - Error analysis
  - Discussion / Results

Note: In case experiment doesn't work, students will not be evaluated for data and data analysis.

Total 100pts, then scaled for notebook check value. We do not assign an actual grade for notebook check 4, but make notebook check 5 worth double or 20% of final grade.

L Senior Exit Survey

Physics Ugrad Exit Survey Fall 2017

Start of Block: Default Question Block

Q1 Thank you for taking the exit survey for graduating Physics students. Your feedback is very important to us!

Q2 If you have decided to attend graduate school, which graduate school will you likely attend AND what department will you be in?

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Q3 If you have decided to work in industry or at a government laboratory, what job will you likely accept? Please provide the position title and company name if possible.

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Q4 If you have decided to work in industry or at a government laboratory, please comment on the preparation you received as a physics major in terms of entering the job market.

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Q5 Did you take the Physics GRE in Spring, Summer or Fall 17? (If no, skip to question #7)

- Yes (1)
- No (2)

Q6 What was your percentile GRE score?

- 100-80% (1)
- 79-60% (2)
- 59-40% (3)
- 39-20% (4)
- 19-0% (5)

Q7 Please provide us with any feedback on how the Department could have better prepared you for graduate school or job searching.

Q8 Did you participate in physics research that was NOT associated with PHYS 483, 492 or 498?

- O Yes, and my research was done in the Physics Department (1)
- O Yes, and my research was done in another UA Department (2)
- O Yes, and my research was done outside the University (3)
- O No (4)

Q9 If you pursued research, employment, or an internship opportunity outside of the Department of Physics during your studies, please share what department/organization/company you worked with and your title.

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Q10 How well did you feel you learned core disciplines (classical mechanics, electromagnetism, quantum mechanics) in physics from your undergraduate classes?

- O Extremely well (1)
- O Very well (2)
- O Moderately well (3)
- O Slightly well (4)
- O Not well at all (5)

Q11 How well did the undergraduate program prepare you to use mathematical or computational skills to investigate physical phenomena?

- O Extremely well (1)
- O Very well (2)
- O Moderately well (3)
- O Slightly well (4)
- O Not well at all (5)

Q12 How well did the undergraduate program prepare you to communicate research results both orally and in writing?

- O Extremely well (1)
- O Very well (2)
- O Moderately well (3)
- O Slightly well (4)
- O Not well at all (5)

M Undergraduate Research Symposium Survey for Faculty

Assessment of Undergraduate Research Presentations

Student # Student gender M F

The student gave an effective oral presentation

5 (high) 4 3 2 1 (low)

The student presented research of such quality that it could have been presented at the APS Four Corner's meeting

5 (high) 4 3 2 1 (low) NA

The student showed an ability to use computational or mathematical skills in order to investigate physical phenomena.

5 (high) 4 3 2 1 (low) NA

The student showed an ability to analyze data.

5 (high) 4 3 2 1 (low) NA

The student showed an ability to critically interpret the results of their work.

5 (high) 4 3 2 1 (low) NA

N Undergraduate Curriculum Map

BS Physics Curriculum Map

Courses and Activities Mapped to BS Physics Outcome Set

	Outcome			
	Outcome 1 Basic Physics Knowledge Physics majors should have significant knowledge of the theories that form the basis of classical mechanics, electromagnetism, quantum mechanics, optics and thermodynamics.	Outcome 2 Critical Thinking Physics majors will be able to design and conduct experiments in order to investigate physical phenomena. They will be able to document, analyze and critically interpret the results of these experiments.	Outcome 3 Skills for Physics Physics majors will be able to use mathematical or computational skills in order to investigate physical phenomena. They will be able to document analyze and critically interpret the results of their work.	Outcome 4 Communication Physics majors will be able to effectively communicate their results through written reports and oral presentations.
Courses and Learning Activities				
Exit Survey Exit Survey for Graduating Seniors	A	A	A	A
PHYS 332 PHYS 332 Electricity and Magnetism II			P	
PHYS 472 Quantum Theory II			P	
PHYS 426 PHYS 426 Thermal Physics	P		P	

	Outcome			
	Outcome 1 Basic Physics Knowledge Physics majors should have significant knowledge of the theories that form the basis of classical mechanics, electromagnetism, quantum mechanics, optics and thermodynamics.	Outcome 2 Critical Thinking Physics majors will be able to design and conduct experiments in order to investigate physical phenomena. They will be able to document, analyze and critically interpret the results of these experiments.	Outcome 3 Skills for Physics Physics majors will be able to use mathematical or computational skills in order to investigate physical phenomena. They will be able to document analyze and critically interpret the results of their work.	Outcome 4 Communication Physics majors will be able to effectively communicate their results through written reports and oral presentations.
PHYS 321 PHYS 321 Theoretical Mechanics	P		P	
PHYS 331 PHYS 331 Electricity and Magnetism I	A		P	
PHYS 371 PHYS 371 Quantum Theory	A		P	
Research Symp. Undergraduate Research Symposium		A	A	A
PHYS 492 PHYS 483/492/498 Research Requirement		P		
PHYS 382 PHYS 382 Methods of Experimental Physics II		A	P	A
PHYS 381				

	Outcome			
	Outcome 1 Basic Physics Knowledge Physics majors should have significant knowledge of the theories that form the basis of classical mechanics, electromagnetism, quantum mechanics, optics and thermodynamics.	Outcome 2 Critical Thinking Physics majors will be able to design and conduct experiments in order to investigate physical phenomena. They will be able to document, analyze and critically interpret the results of these experiments.	Outcome 3 Skills for Physics Physics majors will be able to use mathematical or computational skills in order to investigate physical phenomena. They will be able to document analyze and critically interpret the results of their work.	Outcome 4 Communication Physics majors will be able to effectively communicate their results through written reports and oral presentations.
PHYS 381 Methods of Experimental Physics I		I		I
PHYS 305 PHYS 305 Computational Physics			P	
PHYS 105 PHYS 105 Introdcution to Scientific Computing			I	
PHYS 204 PHYS 204 Mathematical Physics			I	

Legend : I Introduced P Practiced A Assessed

O Ph.D. Requirements

This handbook covers requirements specific for the UA Physics Department. For any UA Graduate College rules and regulations you should consult: grad.arizona.edu and/or grad.arizona.edu/current-students and links therein.

Ph.D. Degree Requirements

1. COURSE WORK

What are the credit hour minimum requirements?
36 in the Physics major (or cross-listed) graduate-level courses
9 in the minor field (which also may be Physics)
18 Dissertation credits (PHYS 920)
At least 50% of the course work in major and minor need to be regularly (A, B…) graded.

Are there any required core courses? No, the core courses are strongly recommended for all students regardless of research direction, but are not required. However, the Comprehensive Examination is based upon the core courses.

PHYS 511 Analytical Mechanics
PHYS 515A/B Electromagnetic Theory
PHYS 570A/B Quantum Mechanics
PHYS 528 Statistical Mechanics

The material studied in the above courses represents what we expect every student to master. However, depending upon student preparation we may recommend to individual students that they take other courses.

For how many credit hours do I need to register each semester? Prior to passing the written portion of the Comprehensive Examination, students are required to take 9 credits per semester. After that, only 6 credits per semester are required.

What is the recommended curriculum?
Year 1, Fall semester: PHYS 570A (QM I), PHYS 511 (CM), PHYS 599
Year 1, Spring semester: PHYS 570B (QM II), PHYS 515A (EM I), PHYS 599
Year 2, Fall semester: PHYS 528 (SM), PHYS 515B (EM II), PHYS 599

What is PHYS 599? PHYS 599 is Independent Study, giving you the opportunity to engage in research with a group or individual faculty immediately after you have entered the program. The Independent Studies are meant for you to explore research areas or groups that you may be considering for your Ph.D. thesis.

Note that no more than half of the 36 required credit hours of graduate-level Physics courses may be taken as PHYS 599. Remaining courses consist of the core courses listed above as well as more advanced specialty courses.

I've entered the Ph.D. program with an MS degree. Can I transfer credits? Yes, you may be able to do so. The DGS will review credits you wish to transfer. Please provide: a detailed list of courses, credits or credit hours for each course, textbook used, grades received, and a syllabus (if available). For Graduate College regulations on transfer of credit visit grad.arizona.edu.

When can I start to register for thesis credits (PHYS 920)? Students may register for PHYS 920 only after they have passed both portions (written and oral) of the Comprehensive Examination. Note that you cannot register for more than 9 PHYS 920 credits per semester.

If I choose Physics as my minor, which courses should I take? If Physics is chosen as the minor as well as the major, the minor requirement is fulfilled by 9 additional credits consisting of at least 3 graduate-level courses. Together, these 3 courses should provide at least three credits from each of 3 of the following eight areas. Courses below are listed merely as examples, and additional courses (including courses from outside the Physics Department) may be considered as part of these areas with the approval of the Director of Graduate Studies.

Classical Mechanics and Mathematical Physics: 513, 541, 575, 576
Atomic, Molecular and Optical Physics: 535, 544(Op.Sci.), 642(Op.Sci.), 648(Op.Sci.)
Condensed Matter Physics: 505, 560A, 560B, 561, 562, 563, 564, 566
Quantum and Particle Physics: 579A, 579B, 581, 584A, 584C
Nuclear Physics: 551, 552
Gravity, Astrophysics and Cosmology: 571, 577, 582, 587, 589, 596b, 596F
Experimental Physics: 505, 545, 573, 574, 586, 685
Biological Physics: 531

It is expected that this minor requirement be satisfied through actual courses rather than Independent Studies. However, exceptions can be granted in special situations.

What if I decide to do my minor in another department? Students choosing a minor in a different department must satisfy whatever minor course requirement(s) that other Department demands. In some cases the minor requirements may include you having to take the Comprehensive Exam in that department. Before you decide on a minor in a department other than Physics, please notify the Director of Graduate Studies (DGS) in Physics and inquire with the DGS in the other department about their minor requirements.

Note that the Graduate College requires you to have **a representative of the minor department on your committee for the Oral portion of the Comprehensive Exam.**

How long is this all going to take? Most of our students graduate during their 5th or 6th year here. Upon entering your 6th year the DGS may request a detailed plan/timeline for completion of the Ph.D..

2. THE COMPREHENSIVE EXAMINATION (WRITTEN AND ORAL PORTION)

2.1 WRITTEN PORTION

What topics does the exam cover? This exam covers classical mechanics, quantum mechanics, electromagnetism, and statistical mechanics at the graduate level. Courses that prepare you for this exam are PHYS 511—Classical Mechanics; PHYS 570A/B—Quantum Mechanics; PHYS 515A/B—E&M; and PHYS 528—Statistical Mechanics.

What is required to pass the written comp? Students need to pass all, 4 out of 4, subjects in order to pass at the **PhD** level. Passing 3 out of 4 subjects is considered a pass for a terminal MS degree.

What is the exam format? Each semester there will be an opportunity to sit for 4 exam subjects: Classical Mechanics, Quantum Mechanics, Electromagnetism, and Statistical Mechanics. Different subject exams are administered on different days (see below): one exam subject per day.

When are the subject exams offered?
Fall semester : Wk 1, Wk, 2 ,Wk 3, Wk 4, Fridays 10am- 1pm (one subject per Friday)
Spring semester : Wk 6, Wk 7, Wk 8, Wk 9 Fridays 10am- 1pm (one subject per Friday)
Times are subject to change depending upon classes/labs/TA responsibilities etc.

When should I take the exam? You can start taking exam subjects immediately after you have arrived here. The recommended exam schedule is tied to core courses offerings:

Core Curriculum	**Written Comp Subjects**
Semester 1, Fall : CM, QM1	CM (Spring, semester 2)
Semester 2, Spring : QM2, EM1	QM (Fall, semester 3)
Semester 3, Fall : EM2, SM	EM, SM (Spring, semester 4)

How do I register for the exam? Exam sessions are announced each semester for the following semester, at which time you are being asked by email to register for the exam with the Graduate Coordinator (gklueders@email.arizona.edu).

Can I practice with previous exams? Yes, consult the senior graduate students and/or the Graduate Coordinator for access to previous exams.

P Professional Science Masters in Medical Physics Requirements

PSM in Medical Physics Degree Requirements

Degree Specifics

Degree Requirements

Students are required to maintain a 3.0 GPA or higher.

First Fall Semester

Medical Physics	PHYS 540	3 units
Project Management	MIS 578	3 units
Radiation Dosimetry	RONC 601A	3 units
Medical Physics Seminar	RONC 596C	1 unit

Total: 10 units

First Spring Semester

Techniques in Particle Physics	PHYS 586	3 units
Experimental Physics	PHYS 544/545	0-6 units*
Therapeutic Radiological Physics	RONC 601B	3 units

Total: 6-12 units

*Choose 3 from 545 A-F

Summer(s)

Internship in Medical Physics 1	3 units

Second Fall Semester

Biomedical Imaging	BME 516	3 units
Health Physics	RONC 502	3 units
Physics Elective/Internship 2	PHYS	3 units

Total: 9 units

Second Spring Semester

Advanced Medical Optics	OPTI 638	3 units
Radiation Biology	RONC 601D	3 units
Physics Electives	PHYS	0-3 units
Total: 6-9 units		

Total units 36+ units

Medical Physics Specialization Courses

Mathematical Methods	PHYS 575	3 units
Human Anatomy and Physiology I	PSIO 201	4 units
Human Anatomy and Physiology II	PSIO 202	4 units

Minor Requirements

none

Q Graduate Curriculum Map

PhD Physics Curriculum Map

Courses and Activities Mapped to PhD Physics Outcome Set

	Outcome			
	Outcome 1 Physics Knowledge Physics Ph.D.'s will have a deep knowledge of the theories that form the basis of classical mechanics, electromagnetism, quantum mechanics and statistical mechanics	Outcome 2 Experimental Skills Physics Ph.D.'s in experimental subfields will be able to design and conduct original experiments in order to investigate physical phenomena. They will be able to analyze data and publish these results in scientific journals.	Outcome 3 Theoretical Skills Physics Ph.D's in theoretical subfields will be able to construct original theories in order to explain or predict physical phenomena. They will be able to describe and publish their work in scientific journals.	Outcome 4 Communication Physics PH.D.'s will be able to effectively communicate their results through written reports and oral presentations.
Courses and Learning Activities				
PhD Survey Post PhD Defense Faculty and Student Survey		A	A	A
PHYS 599 PHYS 599 Independent Study		I	I	
PhD Thesis PhD Thesis		A	A	A
Oral Comp. Oral Comprehensive Exam		P	P	P

	Outcome			
	Outcome 1 Physics Knowledge Physics Ph.D.'s will have a deep knowledge of the theories that form the basis of classical mechanics, electromagnetism, quantum mechanics and statistical mechanics	Outcome 2 Experimental Skills Physics Ph.D.'s in experimental subfields will be able to design and conduct original experiments in order to investigate physical phenomena. They will be able to analyze data and publish these results in scientific journals.	Outcome 3 Theoretical Skills Physics Ph.D's in theoretical subfields will be able to construct original theories in order to explain or predict physical phenomena. They will be able to describe and publish their work in scientific journals.	Outcome 4 Communication Physics PH.D.'s will be able to effectively communicate their results through written reports and oral presentations.
Written Comp. Written Comprehensive Exam	A			
PHYS 528 PHYS 528 Statistical Mechanics	P			
PHYS 570A PHYS 570A Quantum Mechanics	P			
PHYS 515A PHYS 515A Electromagnetic Theory	P			
PHYS 511 PHYS 511 Analytical Mechanics	P			

Legend : I Introduced P Practiced A Assessed

R Unit Profile Data

Make your selections and click APPLY

Career	Plan Type	College	Department	Plan	Academic Year
Undergraduate	Major, Major (Secondary), Preparation	College of Science	Physics	None	Between 2011 - 2017

Majors & Minors

See APR Manual Appendix B, Section A (Item 4), Section H (Items 3a, 4a-c), and Section I (Items 2a, 3b).

						Fall Academic Number of Students							Fall Plan %						
Career	Plan Type	Plan	Academic Plan Code	Subplan	Career Level	2010	2011	2012	2013	2014	2015	2016	2010	2011	2012	2013	2014	2015	2016
Undergraduate	Major	Engineering Physics	EPHBSEPH		BSEPH	4	2						100.0%	100.0%					
		Physics	PHYSBA		BA	3	12	12	17	12	13	8	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			PHYSBS		BS	169	161	138	155	167	191	189	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			PHYSBS2		BS	32	27	19	25	29	24	37	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Major Total					**207**	**201**	**169**	**197**	**208**	**228**	**234**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Undergraduate Total						**207**	**201**	**169**	**197**	**208**	**228**	**234**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Grand Total						**207**	**201**	**169**	**197**	**208**	**228**	**234**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Undergraduate**
and Academic Year is between **2011** and **2017**
and Term Code ends with **4**
and Department Description is equal to **Physics**
and College Description is equal to **College of Science**

Honors Students

See APR Manual Appendix B, Section H (Item 4c).

			Number of Students						
Career	Plan	Subplan	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
UGRD	Engineering Physics		1	1					
	Physics		43	46	42	50	47	55	58
	Physics 2		12	12	8	13	14	7	17
Grand Total			**55**	**58**	**50**	**63**	**61**	**62**	**75**

Honors Status is equal to **Honors Active** , **Honors - 18 units** , **Honors - 24 units** , **Honors - 27 units** , **Honors - 30 units** , **Y**
and IPEDS Classification is less than **8**
and Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and Department Description is equal to **Physics**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Undergraduate**
and College Description is equal to **College of Science**

Honors Students at College Level

See APR Manual Appendix B, Section H (Item 4c).

College Description		Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
College of Science	Number of Honors Students	918	1144	1343	1204	1319	1334	1342
	Number of Undergrad Students in College	5749	5985	6421	6399	6683	6790	6689

Term Code ends with **4**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Undergraduate**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Year is between **2011** and **2017**
and College Description is equal to **College of Science**

Honors Students at University Level

See APR Manual Appendix B, Section H (Item 4c).

	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
Number of Total Undergrad Honors Students	3,311	3,908	4,603	4,186	4,517	4,570	4,682
Number of Undergrad Students Overall	30,592	30,665	31,564	31,669	32,985	33,732	34,072

Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Undergraduate**

Make your selections and click APPLY

Career	Plan Type	College	Department	Plan	Academic Year
Undergraduate	Major, Major (Secondary), Preparation	College of Science	Physics	None	Between 2011 - 2017

Majors & Minors

See APR Manual Appendix B, Section A (Item 4), Section H (Items 3a, 4a-c), and Section I (Items 2a, 3b).

						Fall Academic Number of Students					Fall Plan %				
Career	Plan Type	Plan	Academic Plan Code	Subplan	Academic Level	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Undergraduate	Major	Physics	PHYSBA		Freshman	7	10	7	6	3	58.3%	58.8%	58.3%	46.2%	37.5%
					Junior	2	2	1			16.7%	11.8%	8.3%		
					Senior	2	3	3	5	1	16.7%	17.6%	25.0%	38.5%	12.5%
					Sophomore	1	2	1	2	4	8.3%	11.8%	8.3%	15.4%	50.0%
			PHYSBS		Freshman	48	46	58	68	58	34.8%	29.7%	34.7%	35.6%	30.7%
					Junior	28	30	34	36	37	20.3%	19.4%	20.4%	18.8%	19.6%
					Senior	36	37	37	46	45	26.1%	23.9%	22.2%	24.1%	23.8%
					Sophomore	26	42	38	41	49	18.8%	27.1%	22.8%	21.5%	25.9%
			PHYSBS2		Freshman	2		2	4	6	10.5%		6.9%	16.7%	16.2%
					Junior	4	9	6	4	7	21.1%	36.0%	20.7%	16.7%	18.9%

Rows 1 - 10

Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Undergraduate**
and Academic Year is between **2011** and **2017**
and Term Code ends with **4**
and Department Description is equal to **Physics**
and College Description is equal to **College of Science**

Honors Students

See APR Manual Appendix B, Section H (Item 4c).

			Number of Students						
Career	Plan	Subplan	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
UGRD	Engineering Physics		1	1					
	Physics		43	46	42	50	47	55	58
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Grand Total			**55**	**58**	**50**	**63**	**61**	**62**	**75**

Honors Status is equal to **Honors Active** , **Honors - 18 units** , **Honors - 24 units** , **Honors - 27 units** , **Honors - 30 units** , **Y**
and IPEDS Classification is less than **8**
and Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and Department Description is equal to **Physics**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
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Honors Students at College Level

See APR Manual Appendix B, Section H (Item 4c).

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Term Code ends with **4**
and Academic Year is between **2011** and **2017**
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and Academic Career Description is equal to **Undergraduate**

Make your selections and click APPLY

Career	Plan Type	College	Department	Plan	Academic Year
Undergraduate	Major, Major (Secondary), Preparation	College of Science	Physics	None	Between 2011 - 2017

Majors & Minors

See APR Manual Appendix B, Section A (Item 4), Section H (Items 3a, 4a-c), and Section I (Items 2a, 3b).

						Fall Academic Number of Students							Fall Plan %						
Career	Plan Type	Plan	Academic Plan Code	Subplan	Gender	2010	2011	2012	2013	2014	2015	2016	2010	2011	2012	2013	2014	2015	2016
Undergraduate	Major	Engineering Physics	EPHBSEPH		F	2	1						50.0%	50.0%					
					M	2	1						50.0%	50.0%					
		Physics	PHYSBA		F	1	1	2	2	2	5	2	33.3%	8.3%	16.7%	11.8%	16.7%	38.5%	25.0%
					M	2	11	10	15	10	8	6	66.7%	91.7%	83.3%	88.2%	83.3%	61.5%	75.0%
			PHYSBS		F	32	22	21	31	30	36	41	18.9%	13.7%	15.2%	20.0%	18.0%	18.8%	21.7%
					M	137	139	117	124	137	155	148	81.1%	86.3%	84.8%	80.0%	82.0%	81.2%	78.3%
			PHYSBS2		F	12	11	8	7	6	7	13	37.5%	40.7%	42.1%	28.0%	20.7%	29.2%	35.1%
					M	20	16	11	18	23	17	24	62.5%	59.3%	57.9%	72.0%	79.3%	70.8%	64.9%
	Major Total					**207**	**201**	**169**	**197**	**208**	**228**	**234**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Undergraduate Total						**207**	**201**	**169**	**197**	**208**	**228**	**234**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Rows 1 - 10

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Honors Students

See APR Manual Appendix B, Section H (Item 4c).

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Grand Total			**55**	**58**	**50**	**63**	**61**	**62**	**75**

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Honors Students at University Level

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and Academic Career Description is equal to **Undergraduate**

Make your selections and click APPLY

Career	Plan Type	College	Department	Plan	Academic Year
Undergraduate	Major, Major (Secondary), Preparation	College of Science	Physics	None	Between 2011 - 2017

Majors & Minors

See APR Manual Appendix B, Section A (Item 4), Section H (Items 3a, 4a-c), and Section I (Items 2a, 3b).

						Fall Academic Number of Students							Fall Plan %						
Career	Plan Type	Plan	Academic Plan Code	Subplan	Ethnic Group	2010	2011	2012	2013	2014	2015	2016	2010	2011	2012	2013	2014	2015	2016
Undergraduate	Major	Engineering Physics	EPHBSEPH		White	4	2						100.0 %	100.0 %					
		Physics	PHYSBA		African American					1	2	1					8.3%	15.4%	12.5%
					American Indian			1							8.3%				
					Asian American			1		1	1				8.3%		8.3%	7.7%	
					Hispanic	1	2	2	7	5	3		33.3%	16.7%	16.7%	41.2%	41.7%	23.1%	
					Non Resident Alien	1	1	1	2	1	1	2	33.3%	8.3%	8.3%	11.8%	8.3%	7.7%	25.0%
					Pacific Islander						1							7.7%	
					Unknown / Other		1					1		8.3%					12.5%
					White	1	8	7	8	4	5	4	33.3%	66.7%	58.3%	47.1%	33.3%	38.5%	50.0%
			PHYSBS		African American	5	6	3	6	7	6	7	3.0%	3.7%	2.2%	3.9%	4.2%	3.1%	3.7%

Rows 1 - 10

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Honors Students

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and IPEDS Classification is less than **8**
and Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and Department Description is equal to **Physics**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Undergraduate**
and College Description is equal to **College of Science**

Honors Students at College Level

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Term Code ends with **4**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Undergraduate**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Year is between **2011** and **2017**
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Honors Students at University Level

See APR Manual Appendix B, Section H (Item 4c).

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Number of Undergrad Students Overall	30,592	30,665	31,564	31,669	32,985	33,732	34,072

Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Undergraduate**

Make your selections and click APPLY

Academic Year	Department	Major Plan	Major Plan Code	New Student
Between 2011 - 2017	Physics	None	None	None

SAT and ACT Score by Major

See APR Manual Appendix B, Section D (Item 1), Section H (Item 4a).

		SAT Composite						
Department	Major	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
Physics	Engineering Physics							
	Physics	1249	1196	1236	1252	1241	1215	1301
	Physics 2							

Term Group is equal to / is in **Fall**
and Department Description is equal to **Physics**
and Academic Year is between **2011** and **2017**
and Academic Career Description is equal to / is in **Undergraduate**

SAT and ACT Score by College

See APR Manual Appendix B, Section D (Item 1), Section H (Item 4a).

	SAT Composite						
College Description	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
College of Science	1129	1129	1138	1143	1144	1124	1153

Term Group is equal to / is in **Fall**
and Academic Year is between **2011** and **2017**
and College Id is equal to any **College Id** in **SAT and ACT Score by Major**
and Academic Career Description is equal to / is in **Undergraduate**

SAT and ACT Score University

See APR Manual Appendix B, Section D (Item 1), Section H (Item 4a).

SAT Composite						
Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
1093	1102	1112	1113	1109	1091	1116

Term Group is equal to / is in **Fall**
and Academic Year is between **2011** and **2017**
and Academic Career Description is equal to / is in **Undergraduate**

Make your selections and click APPLY

Career	Academic Organization	Degree	Plan	Fiscal Year >=	Fiscal Year <=
Undergraduate	Physics	BA, BS	Physics, Physics 2	2011	2017

Completed Majors

Fiscal Year is calculated based on August, December, May degree schedule.

See APR Manual Appendix B, Section H (Item 4a), Section I (Item 2a), and Section M. Appendix C.

			Degree Count						
Plan	Degree	Subplan	2011	2012	2013	2014	2015	2016	2017
Physics	BA	Not Available			3		2	3	1
	BS	Not Available	25	24	26	20	20	19	18
Physics Total			**25**	**24**	**29**	**20**	**22**	**22**	**19**

Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Specialization**
and Academic Plan Desc is equal to **Physics** , **Physics 2**
and Degree is equal to **BA** , **BS**
and CASE WHEN Degree Conferral Quarter Year Number > 2 THEN Degree Conferral Year Number + 1 ELSE Degree Conferral Year Number END is less than or equal to **2017**
and Academic Career Desc is equal to **Undergraduate**
and CASE WHEN Degree Conferral Quarter Year Number > 2 THEN Degree Conferral Year Number + 1 ELSE Degree Conferral Year Number END is greater than or equal to **2011**
and Academic Organization Desc is equal to **Physics**

Graduation GPA for Undergraduates/Graduates

See APR Manual Appendix B, Section H (Item 4a).

	Average Graduation GPA							Majors Completed						
Plan Description	2011	2012	2013	2014	2015	2016	2017	2011	2012	2013	2014	2015	2016	2017
Physics	3.42	3.33	3.21	3.18	3.18	3.16	3.43	15	17	23	17	15	17	17
Physics 2	3.52	3.46	3.47	3.29	3.35	3.24	2.93	10	7	6	3	7	5	2

Academic Plan Type is equal to **Major** , **Major 2nd** , **Specialztn**
and Academic Plan Desc is equal to **Physics** , **Physics 2**
and CASE WHEN Degree Conferral Quarter Year Number > 2 THEN Degree Conferral Year Number + 1 ELSE Degree Conferral Year Number END is less than or equal to **2017**
and CASE WHEN Degree Conferral Quarter Year Number > 2 THEN Degree Conferral Year Number + 1 ELSE Degree Conferral Year Number END is greater than or equal to **2011**
and Academic Organization Desc is equal to **Physics**
and Academic Career Desc is equal to **Undergraduate**

Completed Certificates

		2011		2012	2013		2014		2015		2016		2017	
		BA	BS	BS	BA	BS	BA	BS	BA	BS	BA	BS	BA	BS
Plan	Plan Description	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count
PHYSBA	Physics				3				2		3		1	
PHYSBS	Physics		15	17		20		17		13		14		16
PHYSBS2	Physics 2		10	7		6		3		7		5		2
PHYSMINU	Physics	2	7	13	1	6	2	7	1	2	2	8		6

Majors per Completed Majors

Plan	Degree	Subplan	Year	Majors per Completed Major
Physics	BS		2011	3.50
	MS			0.55
	PHD			10.00
Physics	BS		2012	8.76
	MS			0.43
	PHD			6.00
Physics	BA		2013	4.00
	BS			6.75
	MS			0.50
	PHD			6.36

Rows 1 - 10

See APR Manual Appendix B, Section H (Item 4a).

			Majors							Completed Majors							Majors per Completed Major						
Plan	Degree	Subplan	2011	2012	2013	2014	2015	2016	2017	2011	2012	2013	2014	2015	2016	2017	2011	2012	2013	2014	2015	2016	2017
Physics	BA				12.00		10.00	13.00	7.00			3		2	3	1			4.00		5.00	4.33	7.00
	BS		187.00	177.00	163.00	169.00	193.00	217.00	228.00	25	24	26	20	20	19	18	3.50	8.76	6.75	8.18	5.00	6.80	24.50
	MS		6.00	3.00	3.00	5.00	3.00		1.00	11	7	6	4	6		3	0.55	0.43	0.50	1.25	0.50		0.33
	PHD		70.00	72.00	70.00	69.00	73.00	74.00	86.00	7	12	11	8	8	8	12	10.00	6.00	6.36	8.63	9.13	9.25	7.17

Minors for Completed PhD Majors

Minor within major department. See APR Manual Appendix B, Section I (Item 2g).

Degree	Academic Year	Number of Graduates
PHD	2011	6
	2012	11
	2013	6
	2014	7
	2015	5
	2016	5
	2017	10

Minors for Completed PhD Majors

Minor outside major department. See APR Manual Appendix B, Section I (Item 2g).

Degree	Academic Year	Minor	Number of Graduates
PHD	2011	Finance	1
	2011	Astronomy	1
	2012	Economics	2
	2012	Mathematics	1
	2013	Economics	1
	2014	Astronomy	1
	2014	Biochemistry	1
	2014	Biomedical Engineering	1
	2015	Astronomy	2
	2016	Chemistry	1

Rows 1 - 10

Make your selections and click APPLY

Career	Plan Type	College	Department	Plan	Academic Year
Graduate	Major, Major (Secondary), Preparation	College of Science	Physics	None	Between 2011 - 2017

Majors & Minors

See APR Manual Appendix B, Section A (Item 4), Section H (Items 3a, 4a-c), and Section I (Items 2a, 3b).

						Fall Academic Number of Students							Fall Plan %						
Career	Plan Type	Plan	Academic Plan Code	Subplan	Career Level	2010	2011	2012	2013	2014	2015	2016	2010	2011	2012	2013	2014	2015	2016
Graduate	Major	Applied & Industrial Physics	AIPPSM		PSM	7	7	2					100.0%	100.0%	100.0%				
		Medical Physics	MPPSM		PSM			3	9	7	6	4			100.0%	100.0%	100.0%	100.0%	100.0%
		Physics	PHYSMS		MS			1	4	2	1				100.0%	100.0%	100.0%	100.0%	
			PHYSPHD		PHD	74	73	71	71	72	75	87	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Major Total					**81**	**80**	**76**	**80**	**79**	**81**	**90**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Graduate Total						**81**	**80**	**76**	**80**	**79**	**81**	**90**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Grand Total						**81**	**80**	**76**	**80**	**79**	**81**	**90**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Graduate**
and Academic Year is between **2011** and **2017**
and Term Code ends with **4**
and Department Description is equal to **Physics**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Honors Status is equal to **Honors Active** , **Honors - 18 units** , **Honors - 24 units** , **Honors - 27 units** , **Honors - 30 units** , **Y**
and IPEDS Classification is less than **8**
and Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and Department Description is equal to **Physics**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Graduate**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Term Code ends with **4**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Graduate**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Year is between **2011** and **2017**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Graduate**

Make your selections and click APPLY

Career	Plan Type	College	Department	Plan	Academic Year
Graduate	Major, Major (Secondary), Preparation	College of Science	Physics	None	Between 2011 - 2017

Majors & Minors

See APR Manual Appendix B, Section A (Item 4), Section H (Items 3a, 4a-c), and Section I (Items 2a, 3b).

						Fall Academic Number of Students							Fall Plan %						
Career	Plan Type	Plan	Academic Plan Code	Subplan	Gender	2010	2011	2012	2013	2014	2015	2016	2010	2011	2012	2013	2014	2015	2016
Graduate	Major	Applied & Industrial Physics	AIPPSM		F	1	1						14.3%	14.3%					
					M	6	6	2					85.7%	85.7%	100.0%				
		Medical Physics	MPPSM		F						1	1						16.7%	25.0%
					M			3	9	7	5	3			100.0%	100.0%	100.0%	83.3%	75.0%
		Physics	PHYSMS		M			1	4	2	1				100.0%	100.0%	100.0%	100.0%	
			PHYSPHD		F	11	14	12	11	13	13	15	14.9%	19.2%	16.9%	15.5%	18.1%	17.3%	17.2%
					M	63	59	59	60	59	62	72	85.1%	80.8%	83.1%	84.5%	81.9%	82.7%	82.8%
	Major Total					**81**	**80**	**76**	**80**	**79**	**81**	**90**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Graduate Total						**81**	**80**	**76**	**80**	**79**	**81**	**90**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Grand Total						**81**	**80**	**76**	**80**	**79**	**81**	**90**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Graduate**
and Academic Year is between **2011** and **2017**
and Term Code ends with **4**
and Department Description is equal to **Physics**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Honors Status is equal to **Honors Active** , **Honors - 18 units** , **Honors - 24 units** , **Honors - 27 units** , **Honors - 30 units** , **Y**
and IPEDS Classification is less than **8**
and Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and Department Description is equal to **Physics**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Graduate**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Term Code ends with **4**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Graduate**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Year is between **2011** and **2017**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Graduate**

Make your selections and click APPLY

Career	Plan Type	College	Department	Plan	Academic Year
Graduate	Major, Major (Secondary), Preparation	College of Science	Physics	None	Between 2011 - 2017

Majors & Minors

See APR Manual Appendix B, Section A (Item 4), Section H (Items 3a, 4a-c), and Section I (Items 2a, 3b).

						Fall Academic Number of Students							Fall Plan %						
Career	Plan Type	Plan	Academic Plan Code	Subplan	Ethnic Group	2010	2011	2012	2013	2014	2015	2016	2010	2011	2012	2013	2014	2015	2016
Graduate	Major	Applied & Industrial Physics	AIPPSM		Hispanic		1	1						14.3%	50.0%				
					Non Resident Alien	3	3	1					42.9%	42.9%	50.0%				
					White	4	3						57.1%	42.9%					
		Medical Physics	MPPSM		African American				1	1						11.1%	14.3%		
					Asian American			1	2	1	1				33.3%	22.2%	14.3%	16.7%	
					Hispanic				1							11.1%			
					Non Resident Alien			1	2	1		1			33.3%	22.2%	14.3%		25.0%
					White			1	3	4	5	3			33.3%	33.3%	57.1%	83.3%	75.0%
		Physics	PHYSMS		Non Resident Alien				1							25.0%			
					White			1	3	2	1				100.0%	75.0%	100.0%	100.0%	

Rows 1 - 10

Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Graduate**
and Academic Year is between **2011** and **2017**
and Term Code ends with **4**
and Department Description is equal to **Physics**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Honors Status is equal to **Honors Active** , **Honors - 18 units** , **Honors - 24 units** , **Honors - 27 units** , **Honors - 30 units** , **Y**
and IPEDS Classification is less than **8**
and Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and Department Description is equal to **Physics**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Career Description is equal to **Graduate**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Term Code ends with **4**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Graduate**
and Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Preparation**
and Academic Year is between **2011** and **2017**
and College Description is equal to **College of Science**

No Results

The specified criteria didn't result in any data. This is often caused by applying filters and/or selections that are too restrictive or that contain incorrect values. Please check your Analysis Filters and try again. The filters currently being applied are shown below.

Term Code ends with **4**
and Academic Year is between **2011** and **2017**
and IPEDS Classification is less than **8**
and Academic Career Description is equal to **Graduate**

Make your selections and click APPLY

Career	Academic Organization	Degree	Plan	Fiscal Year >=	Fiscal Year <=
Graduate	Physics	MS, PHD, PSM	Physics	2011	2017

Completed Majors

Fiscal Year is calculated based on August, December, May degree schedule.

See APR Manual Appendix B, Section H (Item 4a), Section I (Item 2a), and Section M. Appendix C.

			Degree Count						
Plan	Degree	Subplan	2011	2012	2013	2014	2015	2016	2017
Physics	MS	Not Available	11	7	6	4	6	1	3
	PHD	Not Available	7	12	11	8	8	8	12
Physics Total			**18**	**19**	**17**	**12**	**14**	**9**	**15**

Academic Plan Type Desc is equal to **Major** , **Major (Secondary)** , **Specialization**
and Academic Plan Desc is equal to **Physics**
and Degree is equal to **MS** , **PHD** , **PSM**
and CASE WHEN Degree Conferral Quarter Year Number > 2 THEN Degree Conferral Year Number + 1 ELSE Degree Conferral Year Number END is less than or equal to **2017**
and Academic Career Desc is equal to **Graduate**
and CASE WHEN Degree Conferral Quarter Year Number > 2 THEN Degree Conferral Year Number + 1 ELSE Degree Conferral Year Number END is greater than or equal to **2011**
and Academic Organization Desc is equal to **Physics**

Graduation GPA for Undergraduates/Graduates

See APR Manual Appendix B, Section H (Item 4a).

	Average Graduation GPA							Majors Completed						
Plan Description	2011	2012	2013	2014	2015	2016	2017	2011	2012	2013	2014	2015	2016	2017
Physics	3.64	3.60	3.64	3.65	3.65	3.69	3.70	18	19	17	12	14	9	15

Academic Plan Type is equal to **Major** , **Major 2nd** , **Specialztn**
and Academic Plan Desc is equal to **Physics**
and CASE WHEN Degree Conferral Quarter Year Number > 2 THEN Degree Conferral Year Number + 1 ELSE Degree Conferral Year Number END is less than or equal to **2017**
and CASE WHEN Degree Conferral Quarter Year Number > 2 THEN Degree Conferral Year Number + 1 ELSE Degree Conferral Year Number END is greater than or equal to **2011**
and Academic Organization Desc is equal to **Physics**
and Academic Career Desc is equal to **Graduate**

Completed Certificates

		2011		2012		2013		2014		2015		2016		2017	
		MS	PHD	MS	PHD	MS	PHD	MS	PHD	MS	PHD	MS	PHD	MS	PHD
Plan	Plan Description	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count	Certificates Count
PHYSMING	Physics		4		11		11		8		7		6		11
PHYSMS	Physics	11		7		6		4		6		1		3	
PHYSPHD	Physics		7		12		11		8		8		8		12

Majors per Completed Majors

Plan	Degree	Subplan	Year	Majors per Completed Major
Physics	BS		2011	3.50
	MS			0.55
	PHD			10.00
Physics	BS		2012	8.76
	MS			0.43
	PHD			6.00
Physics	BA		2013	4.00
	BS			6.75
	MS			0.50
	PHD			6.36

Rows 1 - 10

See APR Manual Appendix B, Section H (Item 4a).

			Majors							Completed Majors							Majors per Completed Major						
Plan	Degree	Subplan	2011	2012	2013	2014	2015	2016	2017	2011	2012	2013	2014	2015	2016	2017	2011	2012	2013	2014	2015	2016	2017
Physics	BA				12.00		10.00	13.00	7.00			3		2	3	1			4.00		5.00	4.33	7.00
	BS		187.00	177.00	163.00	169.00	193.00	217.00	228.00	25	24	26	20	20	19	18	3.50	8.76	6.75	8.18	5.00	6.80	24.50
	MS		6.00	3.00	3.00	5.00	3.00		1.00	11	7	6	4	6		3	0.55	0.43	0.50	1.25	0.50		0.33
	PHD		70.00	72.00	70.00	69.00	73.00	74.00	86.00	7	12	11	8	8	8	12	10.00	6.00	6.36	8.63	9.13	9.25	7.17

Minors for Completed PhD Majors

Minor within major department. See APR Manual Appendix B, Section I (Item 2g).

Degree	Academic Year	Number of Graduates
PHD	2011	6
	2012	11
	2013	6
	2014	7
	2015	5
	2016	5
	2017	10

Minors for Completed PhD Majors

Minor outside major department. See APR Manual Appendix B, Section I (Item 2g).

Degree	Academic Year	Minor	Number of Graduates
PHD	2011	Finance	1
	2011	Astronomy	1
	2012	Economics	2
	2012	Mathematics	1
	2013	Economics	1
	2014	Astronomy	1
	2014	Biochemistry	1
	2014	Biomedical Engineering	1
	2015	Astronomy	2
	2016	Chemistry	1

Rows 1 - 10

Make your selections and click APPLY

College	Department	Fiscal Year Range (20## - 20##)
College of Science	Physics	Between 11 - 17

Student Credit Hours and Full Time Equivalency

See APR Manual Appendix B, Section H (Item 3a), Section I (Item 2a).

			FY 2011				FY 2012				FY 2013			
			Fall 2010		Spring 2011		Fall 2011		Spring 2012		Fall 2012		Spring 2013	
College	Department	Level	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE
College of Science	Physics	Undergraduate	6,268	430.42	6,418	439.53	6,491	442.89	6,850	466.90	6,363	434.73	7,313	496.82
		Graduate	404	40.40	419	41.90	404	40.42	400	39.97	480	47.97	389	38.92
	Physics Total		**6,672**	**470.83**	**6,837**	**481.43**	**6,895**	**483.30**	**7,250**	**506.86**	**6,843**	**482.70**	**7,703**	**535.74**
College of Science Total			**6,672**	**470.83**	**6,837**	**481.43**	**6,895**	**483.30**	**7,250**	**506.86**	**6,843**	**482.70**	**7,703**	**535.74**

			FY 2014				FY 2015				FY 2016				FY 2017			
			Fall 2013		Spring 2014		Fall 2014		Spring 2015		Fall 2015		Spring 2016		Fall 2016		Spring 2017	
College	Department	Level	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE	Distributed SCH	FTE
College of Science	Physics	Undergraduate	6,058	411.51	6,754	460.32	6,817	463.26	7,677	522.80	6,845	466.21	7,713	525.82	6,421	440.24	7,408	505.64
		Graduate	450	45.00	357	35.70	404	40.40	435	43.50	476	47.60	450	45.00	582	58.20	489	48.90
	Physics Total		**6,508**	**456.51**	**7,111**	**496.02**	**7,221**	**503.66**	**8,112**	**566.30**	**7,321**	**513.81**	**8,163**	**570.82**	**7,003**	**498.44**	**7,897**	**554.54**
College of Science Total			**6,508**	**456.51**	**7,111**	**496.02**	**7,221**	**503.66**	**8,112**	**566.30**	**7,321**	**513.81**	**8,163**	**570.82**	**7,003**	**498.44**	**7,897**	**554.54**

College Description is equal to **College of Science**
and Department Description is equal to **Physics**
and Subject Code is not equal to / is not in **GS** , **COOP** , **NSE** , **ARU**
and Class Section Code is not LIKE (pattern match) **75%** , **9%** , **70%** , **80%**
and Term Description is LIKE (pattern match) **Fall%** , **Spring%**
and Fiscal Year is greater than or equal to **10**
and Fiscal Year is between **11** and **17**

Make your selection and click APPLY

Job Department

Accounting

Personnel FTE (includes state and other fund groups)

Data Available Beginning Fall 2010

See APR Manual Appendix B, Section A (Items 2-3), Section F (Item 2).

Accounting

		Head Count							Total FTE						
ABOR Code	Faculty Tenure	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016
Administrative	-	1	1	1	1	1	1	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Classified Staff	-	5	5	7	7	6	6	7	3.750	3.750	4.500	4.500	3.500	4.000	5.000
	Non-Tenure Eligible			1							0.500				
Faculty	-	12	14	10	11	11	8	6	10.260	9.600	6.850	6.830	6.500	3.650	2.750
	Multi-year	3	3	3	3	3	3	3	3.000	3.000	3.000	3.000	3.000	3.000	3.000
	Non-Tenure Eligible	5	4	5	7	8	9	11	3.440	3.500	3.500	4.000	4.850	5.050	6.350
	Tenure Eligible			2	2	4	4	4			2.000	2.000	4.000	4.000	4.000
	Tenured	2	3	3	3	3	5	5	2.000	3.000	3.000	3.000	3.000	5.000	4.600
Graduate Assistant/Associate	-	30	30	36	43	43	42	45	11.000	10.000	12.000	14.000	14.750	15.000	15.000
Service Professional	-						1							1.000	
Student Worker	-	1	1	1					0.370	0.280	0.500				
Grand Total		**59**	**61**	**69**	**77**	**79**	**79**	**82**	**34.820**	**34.130**	**36.850**	**38.330**	**40.600**	**41.700**	**41.700**

State Funded Personnel FTE

Data Available Beginning Fall 2010

See APR Manual Appendix B, Section A (Items 2-3), Section F (Item 2).

Accounting

			Headcount								Total FTE							
ABOR Code	Faculty Tenure	Account Fund Group Long Desc	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2017	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2017
Administrative	-	STATE	1	1	1	1	1	1	1	1	1.00	1.00	1.00	0.80	0.80	0.80	0.80	0.80
Classified Staff	-	STATE	5	5	7	7	6	6	6	5	3.75	3.75	4.50	4.25	3.25	3.75	3.75	3.25
	Non-Tenure Eligible	STATE			1								0.50					
Faculty	-	STATE	12	14	9	10	10	7	6	1	10.26	9.60	6.60	5.98	5.60	3.20	2.63	0.80
	Multi-year	STATE	3	3	3	3	3	3	3	3	3.00	3.00	3.00	3.00	2.77	2.77	2.77	2.43
	Non-Tenure Eligible	STATE	5	4	5	7	8	9	11	12	3.44	3.50	3.50	3.30	4.23	4.68	6.35	6.65
	Tenure Eligible	STATE			2	2	4	4	4	6			2.00	2.00	4.00	4.00	4.00	5.44
	Tenured	STATE	2	3	3	3	3	5	5	7	2.00	3.00	3.00	2.80	2.74	4.54	4.20	5.72
Graduate Assistant/Associate	-	STATE	30	30	36	43	43	42	45	41	11.00	10.00	12.00	14.00	14.75	15.00	15.00	14.25
Service Professional	-	STATE								3								0.75
Grand Total			**58**	**60**	**67**	**76**	**78**	**77**	**81**	**79**	**34.45**	**33.85**	**36.10**	**36.13**	**38.14**	**38.74**	**39.50**	**40.09**

Make your selections and click APPLY

Career

Undergraduate

Academic Organization

Accounting

Year <=

2017

Majors per State Funded Tenure Track & Administrative Faculty FTE

Data Available Beginning Fall 2010

See APR Manual Appendix B, Section E (Item e4).

Career	Plan	Subplan	Term	Fall Plan Count	FTE Count	Majors per FTE
Undergraduate	Accounting	-	Fall 2010	330.00	13.66	24.16
			Fall 2011	318.00	13.50	23.56
			Fall 2012	297.00	11.50	25.83

Completed Majors per State Funded Tenure Track & Administrative Faculty FTE

Data Available Beginning Fall 2010

See APR Manual Appendix B, Section E (Item e4).

Career	Plan	Subplan	Term	Degree	Degree Count	FTE Count	Majors per FTE
Undergraduate	Accounting	Not Available	Fall 2010	BSBA	171.00	13.66	12.52
			Fall 2011	BSBA	165.00	13.50	12.22
			Fall 2012	BSBA	167.00	11.50	14.52

Make your selections and click APPLY

Department	Fiscal Year >=	Fiscal Year <=
Physics	2011	2017

State Expenditures
Data Available Beginning Fiscal Year 2009

See APR Manual, Appendix B, Section G.

	State Expenditures						
Department	2011	2012	2013	2014	2015	2016	2017
Physics	4,548,708.01	4,493,031.04	4,743,246.11	4,411,987.47	4,602,184.97	5,264,231.96	5,785,036.29
Grand Total	**4,548,708.01**	**4,493,031.04**	**4,743,246.11**	**4,411,987.47**	**4,602,184.97**	**5,264,231.96**	**5,785,036.29**

State Expenditures / Completed Major
Data Available Beginning Fiscal Year 2009

See APR Manual, Appendix B, Section G.

Physics

Fiscal Year	State Expenditures	Completed Majors	State Expenditure per Completed Major
2011	4,548,708.01	46	98,884.96
2012	4,493,031.04	49	91,694.51
2013	4,743,246.11	47	100,920.13
2014	4,411,987.47	36	122,555.21
2015	4,602,184.97	39	118,004.74
2016	5,264,231.96	35	150,406.63
2017	5,785,036.29	38	152,237.80

Make your selections and click APPLY

Department	Fiscal Year
Physics	Between 2011 - 2017

Sponsored Project Expenditures
Data Available Beginning Fiscal Year 2009

See APR Manual, Appendix B, Section D (Item 1), Section E (Item 2).

	Sponsored Project Expenditures						
Department	2011	2012	2013	2014	2015	2016	2017
Physics	5,150,866.74	4,492,578.01	4,170,338.41	4,308,226.22	4,577,201.59	4,424,152.16	4,617,433.59

Fiscal Year is between **2011** and **2017**
and Basic Accounting Category Code is equal to **EX**
and Period Number is equal to **13**
and Fund Group Name is equal to **Sponsored Projects**
and Sub Account Type Code is equal to **-** , **EX**
and Chart Code is equal to / is in **UA**
and Organization Rollup Department Name is equal to **Physics**