Executive Summary

Request for Authorization to Implement BS in Applied Physics

<table>
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<tr>
<th>Requested by</th>
<th>Department of Physics, College of Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIP Code</td>
<td>14.1201 Engineering Physics/Applied Physics</td>
</tr>
</tbody>
</table>

Purpose of Program

The 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.

The major is designed to serve undergraduates intending to (a) enter the workforce in the engineering, information technology, life sciences or financial sector, or (b) obtain advanced degrees in a related field such as engineering, chemistry or medicine, or (c) obtain educational or government positions in science and public policy.

The program requires a total of 59 units in the major consisting of 19 units of introductory physics coursework, 16 units of upper division physics coursework, 3 units of communication coursework, 3 units of data analysis/statistics/modeling, 12 units of technical electives chosen in consultation with a faculty advisor, and 6 units of senior engineering design project.

Upon successful completion of the program, students will be able to demonstrate the following learning outcomes:

1. Core knowledge that form the basis of classical mechanics, quantum mechanics, electromagnetism, optics and thermodynamics

2. Design, conduct, and analyze experiments to optimize engineering research and development and to investigate underlying physical phenomena.

3. Ability to communicate experimental results and to present engineering design solutions in written and oral form.

4. Proficiency in using mathematical or computational skills to investigate physical phenomena or to optimize solutions to technological problems.

5. Ability to work in multidisciplinary teams to address technological problems arising in academic, government or private sectors.

5-year projected annual enrollment
<table>
<thead>
<tr>
<th>Source(s) of Funding</th>
<th>1st year</th>
<th>2nd year</th>
<th>3rd year</th>
<th>4th year</th>
<th>5th year</th>
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<tr>
<td></td>
<td>Low: 12</td>
<td>Low: 36</td>
<td>Low: 68</td>
<td>Low: 93</td>
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<td>High: 66</td>
<td>High: 102</td>
<td>High: 134</td>
<td>High: 150</td>
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</tbody>
</table>
| Source(s) of Funding | Continuing Sources:  
|                      | - UG RCM Revenue  
| Expenditure Items:   |                       
|                      | - Additional lecturer anticipated  
|                      | - Additional 0.5 academic advisor  
|                      | - Additional 10 hrs/wk student worker |

**Approvals:**
- ABOR: 2/08/2019
- Undergraduate Council: 2/12/2019
- Graduate Council: N/A
- CAAC: 12/18/2018
- Provost’s Council: 3/11/2019
- Faculty Senate: 3/11/2019
New Academic Program Workflow Form

General

**Proposed Name:** Applied Physics

Transaction Nbr: 00000000000010

Plan Type: Major

Academic Career: Undergraduate

Degree Offered: Bachelor of Science

Do you want to offer a minor? N

Anticipated 1st Admission Term: Fall 2019

Details

Department(s):

**SCNC**

<table>
<thead>
<tr>
<th>DEPTMNT ID</th>
<th>DEPARTMENT NAME</th>
<th>HOST</th>
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<tbody>
<tr>
<td>0411</td>
<td>Physics</td>
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Campus(es):

**MAIN**

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<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>TUCSON</td>
<td>Tucson</td>
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</table>

Admission application terms for this plan: Spring: Y Summer: Y Fall: Y

Plan admission types:

Freshman: Y  Transfer: Y  Readmit: Y  Graduate: N

Non Degree Certificate (UCRT only): N

Other (For Community Campus specifics): N

Plan Taxonomy: 14.1201, Engineering Physics
Program Length Type: Program Length Value: 0.00
Report as NSC Program:
SULA Special Program:

Print Option:
Diploma: Y  Bachelor of Science in Applied Physics
Transcript: Y  Bachelor of Science degree, Major in Applied Physics

Conditions for Admission/Declaration for this Major:
None

Requirements for Accreditation:
None

Program Comparisons

University Appropriateness

The Applied Physics major aligns with the working draft of the UA Strategic Plan (2018). One of the five pillars of the Strategic Plan is "The Wildcat Journey: Driving Student Success for a Rapidly Changing World". One of the goals at UA is to provide students with "the skills and mindsets to lead in the 4th Industrial Revolution". The unique components of the Applied Physics major directly inform on this goal. The degree emphasizes skills such as computing, statistics, communications, and teamwork that are essential in order to succeed and lead in the 4th Industrial Revolution.

The above skills cannot be used by themselves. There must be a solid core of fundamental knowledge in some discipline, physics in this case, to which the tools are applied. The ranking of the UA physics department at #37 by US News and World Report shows the excellent quality of scholarship and research of the UA physics program.

ASU does offer an Applied Physics program at their Polytechnic campus. The target students are those seeking jobs with local industry such as Intel and other technical companies in the Phoenix area, and the program heavily emphasizes quantum mechanics. The proposed UA Applied Physics major is more flexible and can be geared toward other sectors such as pharmaceuticals, alternative energy and environmental engineering.

The Applied Physics major is also consistent with the UA College of Science (COS) 2014-2018 Strategic Plan. The mission of the College of Science is to encourage the aggressive pursuit of research excellence, support novel teaching and outreach programs, and create economic opportunities for our community. Among the strategies of the COS is one to "invest in synergy, combining
investments in people, technologies, and communities". By combining a rigorous physics degree with important elements from computational science, statistics, communication skills, and real-world experiences, the Applied Physics major increases employment potential for students. The new major also aligns with three (of several) specific goals discussed in the Strategic Plan: Recruit diverse undergraduates, increase the number of bachelor degrees (especially in high demand fields), and educate students who will be sought out by the best employers. The attainment of all of these goals will be greatly supported by the Applied Physics major.

**Arizona University System**

<table>
<thead>
<tr>
<th>NBR</th>
<th>PROGRAM</th>
<th>DEGREE</th>
<th>#STDNTS</th>
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<tr>
<td>1</td>
<td>Applied Physics</td>
<td>BS</td>
<td>22</td>
<td>ASU Polytechnic Campus</td>
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</table>

**Peer Comparison**

Four of our 15 peer institutions offer a program specifically labeled "Applied Physics". In two of these institutions (University of Washington and Ohio State University), Applied Physics is offered as a track or option in a single Bachelor of Science degree in physics. The other two institutions (UC Davis and University of Iowa) offer a separate BS in Applied Physics, through the same department that offers the BS in Physics.

The comparison chart shows the UA major alongside those of Washington, Davis and ASU. Our program is quite similar to those at Washington and UC Davis, though closer to UC Davis in that we also propose a separate BS in Applied Physics. The chief curricular difference is that Washington and UC Davis further subdivide Applied Physics into various tracks (e.g., biophysics, astrophysics etc.), whereas we will implement this at the advising level. Focused technical electives (12 units) and the statistics/data science option (3 units) will be selected in close consultation with an advisor, based on student's post-academic goals.

The required math and physics coursework is quite similar among UA, Washington and UC Davis. However, our program emphasizes communication and interdisciplinary work to a greater degree, requiring that the capstone project explicitly involve engineering design in teams.

ASU's Applied Physics program appears geared towards the local tech sector, requiring 3 semesters of quantum mechanics and a course in nanoscience, whereas we require only one semester of upper-division quantum mechanics and allow the student's career focus to determine the technical electives.

Finally, we compare the proposed Applied Physics major with our current 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, 492 or 498). Applied Physics adds the following requirements (which are not in Physics): communication course (3 units), data analysis course (3 units), focused technical electives (12 units), and the engineering design project (6 units). All other requirements are the same.

Faculty & Resources

Faculty

Current Faculty:

<table>
<thead>
<tr>
<th>INSTR ID</th>
<th>NAME</th>
<th>DEPT</th>
<th>RANK</th>
<th>DEGREE</th>
<th>FCLTY/%</th>
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</thead>
<tbody>
<tr>
<td>22063577</td>
<td>Samuel Gralla</td>
<td>0411</td>
<td>Assit. Prof</td>
<td>Doctor of Philosophy</td>
<td>40.00</td>
</tr>
<tr>
<td>05303876</td>
<td>Kenneth Johns</td>
<td>0411</td>
<td>Professor</td>
<td>Doctor of Philosophy</td>
<td>20.00</td>
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<tr>
<td>22063849</td>
<td>Stefan Meinel</td>
<td>0411</td>
<td>Assit. Prof</td>
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<tr>
<td>05807819</td>
<td>Fulvio Melia</td>
<td>0411</td>
<td>Professor</td>
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</tr>
<tr>
<td>04205775</td>
<td>Johann Rafelski</td>
<td>0411</td>
<td>Professor</td>
<td>Doctor of Philosophy</td>
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<tr>
<td>22063432</td>
<td>Eduardo Rozo</td>
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<td>Assit. Prof</td>
<td>Doctor of Philosophy</td>
<td>40.00</td>
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<tr>
<td>04603168</td>
<td>John Rutherfoord</td>
<td>0411</td>
<td>Professor</td>
<td>Doctor of Philosophy</td>
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<tr>
<td>04709789</td>
<td>Sumitendra Mazumdar</td>
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<td>Professor</td>
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<tr>
<td>09303616</td>
<td>Elliott Cheu</td>
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<tr>
<td>13509769</td>
<td>Alexander Cronin</td>
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<tr>
<td>11309655</td>
<td>Keith Dienes</td>
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<tr>
<td>15300630</td>
<td>Sean Fleming</td>
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<tr>
<td>12201990</td>
<td>Ubirajara Van Kolck</td>
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<tr>
<td>13504146</td>
<td>Erich Varnes</td>
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<tr>
<td>11208958</td>
<td>Koen Visscher</td>
<td>0411</td>
<td>Assoc. Prof</td>
<td>Doctor of Philosophy</td>
<td>60.00</td>
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<tr>
<td>22057315</td>
<td>Weigang Wang</td>
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<tr>
<td>08609669</td>
<td>Charles Wolgemoth</td>
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<tr>
<td>17200873</td>
<td>Shufeng Zhang</td>
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<td>12200030</td>
<td>John Milsom</td>
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<tr>
<td>01013523</td>
<td>Shawn Jackson</td>
<td>0411</td>
<td>Senior Lecturer</td>
<td>Doctor of Philosophy</td>
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<tr>
<td>22078508</td>
<td>Alex Burant</td>
<td>0411</td>
<td>Lecturer</td>
<td>Doctor of Philosophy</td>
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<tr>
<td>22074672</td>
<td>Mohammed Mohammed</td>
<td>0411</td>
<td>Assit. Prof</td>
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<tr>
<td>14703627</td>
<td>Andrei Lebed</td>
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<td>15901811</td>
<td>Brian LeRoy</td>
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<td>04606107</td>
<td>Ina Sarcevic</td>
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<td>04604361</td>
<td>William Toussaint</td>
<td>0411</td>
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Additional Faculty:

Due to the anticipated increase in undergraduate student load, a lecturer will be added in Year 4, if we reach the prescribed enrollment targets (see high and low projection budgets).

Current Student & Faculty FTE

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<tr>
<th>DEPARTMENT</th>
<th>UGRD HEAD COUNT</th>
<th>GRAD HEAD COUNT</th>
<th>FACULTY FTE</th>
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Projected Student & Faculty FTE

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<td>115</td>
<td>28.02</td>
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Library

Acquisitions Needed:

None
Physical Facilities & Equipment

Existing Physical Facilities:
Existing Facilities Adequate

Additional Facilities Required & Anticipated:
None

Other Support

Other Support Currently Available:
0.5 Advisor position Holly Brown
Academic Support Office position Karina Valdez
60 hours per week of student worker time

Other Support Needed over the Next Three Years:
Additional 0.5 academic advisor
Additional 10 hours per week of student work

Comments During Approval Process

12/8/2018 9:11 PM
MAZUMDAR

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<tr>
<th>Comments</th>
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12/9/2018 10:12 AM
ECHEU

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NEW ACADEMIC PROGRAM-UNDERGRADUATE MAJOR
ADDITIONAL INFORMATION FORM

I. PURPOSE AND NATURE OF THE MAJOR—provide a description for the proposed program. Include the purpose, nature, and highlights. The description will be displayed on the advisement report and should match departmental and college websites, handouts, promotional materials, etc.

We propose a new major in Applied Physics alongside 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 other sectors such as military, education and public policy. We further propose to eliminate our current BA degree, which is currently undersubscribed (only 9 degrees awarded since Fall 2012), effectively replacing it with the professionally focused and marketable BS in Applied Physics.

Based on an informal audit of physics departments at major research universities, around one-third offer an additional applied physics degree or track consistent with the current proposal. Out of our 15 peer institutions, for example:
  - Nine do not offer an Applied Physics program
  - Two are actively developing an Applied Physics program to be offered in the near future (University of Illinois and UNC Chapel Hill)
  - Two currently offer Applied Physics as a separate track or option for their BS in Physics (Ohio State and University of Washington)
  - Two currently offer Applied Physics as a separate BS degree through the department of physics (UC Davis and University of Iowa)

Applied Physics programs are clearly on the rise, as evidenced by the two programs in development. We strongly believe that the fourth option (separate BS in Applied Physics) makes the most sense at UA. We already have an institutional history of offering separate BS degrees in Astronomy, Atmospheric Sciences and Optical Science & Engineering. Despite the
superficial overlap between these programs and physics, it is recognized that the non-overlapping parts of the curricula are crucial in preparing students for distinct professional goals. The same is true for Applied Physics.

The proposed BS in Applied Physics is designed to serve undergraduates intending to (a) enter the workforce in the engineering, information technology, life sciences or financial sector, or (b) obtain advanced degrees in a related field such as engineering, chemistry or medicine, or (c) obtain educational or government positions in science and public policy. This group will be distinct from traditional Physics majors. Although there is some overlap in required coursework, Applied Physics majors will eliminate 18 units of upper-division physics and add 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. (For comparison, the current BS in Astronomy and BS in Physics are separated by 19 units of required coursework.)

The new major will mitigate the current shortfall in retention and training of physics majors. Only about half of incoming physics majors graduate in the major, with most others switching to engineering, astronomy, optical sciences etc., or leaving the university. By reducing the number of demanding upper-division physics courses, we anticipate reducing the attrition rate to 20-30% as physics majors switch to Applied Physics as a practical alternative. We also anticipate that the new major will attract a substantial number of new incoming students, particularly among underrepresented minorities, for whom training to enter the private employment sector is an overriding concern.
II. **MAJOR REQUIREMENTS**—complete the table below to list the major requirements, including minimum number of credit hours, required core, electives, and any special requirements, including sub-plans, theses, internships, etc. Note: information in this section must be consistent throughout the proposal documents (comparison charts, department checklists, curricular/assessment map, etc.). Delete the **EXAMPLE** column before submitting/uploading. Complete table found in Appendix A if requesting a corresponding minor.

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<th>Total units required to complete degree</th>
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<td>Upper-division units required to complete degree</td>
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<th>Foundation courses</th>
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<th>General education requirements</th>
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<td>2 courses/ 6 units-Tier I 160 (TRAD)</td>
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<td>3 units-Tier II Arts</td>
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<tr>
<td>1 course/ 3 units-Tier II Humanities</td>
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<tr>
<td>1 course/ 3 units-Tier II Individuals and Societies</td>
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<tr>
<th>Pre-major? (Yes/No. If yes, provide requirements). Provide email(s)/letter(s) of support from home department head(s) for courses not owned by your department.</th>
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</thead>
<tbody>
<tr>
<td>No</td>
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<table>
<thead>
<tr>
<th>List any special requirements to declare or gain admission to this major (completion of specific coursework, minimum GPA, interview, application, etc.)</th>
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<tbody>
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<td>No specific requirements. 2.0 GPA required to change into major as a current student.</td>
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<table>
<thead>
<tr>
<th>Major requirements</th>
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<tr>
<td>Minimum # of units required in major (units counting towards major units and major GPA)</td>
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<tr>
<td>Minimum # of upper-division units required in the major (upper division units counting towards major GPA)</td>
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**Minimum # of residency units to be completed in the major**

| 30 |

**Required supporting coursework (courses that do not count towards major units and major GPA, but are required for the major). Courses listed must include subject code, units, and title. Include any limits/restrictions needed (house number limit, etc.). Provide email(s)/letter(s) of support from home department head(s) for courses not owned by your department.**

- MATH 122A/B or 125 (5/4) Calculus I
- MATH 129 (3) Calculus II
- MATH 223 (4) Vector Calculus
- MATH 254 (3) Introduction to Ordinary Differential Equations

**Major requirements (list all required major coursework including major core, major electives, sub-plan core, and sub-plan electives; courses count towards major units and major GPA) Courses listed must include course prefix, number, units, and title. Mark new coursework (New). Include any limits/restrictions needed (house number limit, etc.). Provide email(s)/letter(s) of support from home department head(s) for courses not owned by your department.**

**Applied Physics, Introductory course requirements.** During the first two years, students must complete 19 units of coursework in physics, listed below. For the Honors courses, we do not require that majors be honors students; non-honors students will be added manually through the Academic Support Office, as we currently do with BS Physics majors. Transfer students from community colleges with equivalent Phys 141 or 241 credit will be allowed to substitute that credit for the 161H and 261H requirements respectively.

- PHYS 105A (1 unit), Introduction to Scientific Computing
- PHYS 161H (4 units), Honors Introductory Mechanics
- PHYS 162H (4 units), Honors Introductory Optics and Thermodynamics
- PHYS 261H (4 units), Honors Introductory Electricity and Magnetism
- PHYS 263H (3 units), Honors Introductory Relativity and Quantum Physics
- PHYS 204 (3 units), Mathematical Techniques 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 coursework and project experience, listed below.
Required Physics courses (16 units):  
PHYS 305 (3 units), Computational Physics  
PHYS 321 (3 units), Theoretical Mechanics  
PHYS 331 (3 units), Electricity & Magnetism I  
PHYS 371 (3 units), Quantum Theory  
PHYS 381 (2 units), Methods in Experimental Physics I  
PHYS 382 (2 units), Methods of Experimental Physics II

Communication course (3 units):  
One course from the following:  COMM/PR 119 (Public Speaking), ENGL 308 (Technical Writing), 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. This list is expected to evolve over the years as some courses become defunct and new courses are added by these or other departments.

Data analysis/statistics/modeling (3 units):  
One course from the following:  ISTA 311 (Foundation of Information and Inference), ISTA 350 (Programming for Informatics Applications), 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. This list is expected to evolve over the years as some courses become defunct and new courses are added by these or other departments.

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. We will work closely with engineering, optical sciences and other department to develop course sequences in concentration areas of likely interest to students (e.g., alternative energy, signal processing, nanomaterials, etc.). While this will be an evolving list, here are some examples of technical electives that can fulfill this requirement: CHEM 241A-B, CHEM 325, BIOC 384, OPTI 306, OPTI 341, BME 214, MSE 331R, MSE 365, SIE 305, SIE 414, CHEE 326, CHEE 302, ECE 304A, ECE 352, AME 320, AME 331, HWRS 340, HWRS 350

Senior engineering design project (6 units):
ENGR 498A (Cross-disciplinary Design) and ENGR 498B (Cross-disciplinary Design) or 6 units of PHYS 494, in the event that an equivalent team experience can be found in the private sector.

| Internship, practicum, applied course requirements (Yes/No. If yes, provide description) | No |
| Senior thesis or senior project required (Yes/No. If yes, provide description) | Yes. Students will take 6 units consisting of ENGR 498A (3) and ENGR 498B (3). Students work in cross-disciplinary teams of four or five on projects funded by industry. The requirement can also be satisfied with 6 units of PHYS 494 with special permission and in the event that an equivalent team experience can be found in the private sector. |
| Additional requirements (provide description) | None |
| Minor (specify if optional or required) | Optional |
| Any double-dipping restrictions? (Yes/No. If yes, provide description) | No |
### III. CURRENT COURSES

Using the table below, list existing courses included in the proposed major. If the courses listed belong to a department that is not a signed party to this implementation request, upload the department head’s permission to include the courses in the proposed program and information regarding accessibility to and frequency of offerings for the course(s). Upload letters of support/emails from department heads to the “Letter(s) of Support” field on the UAccess workflow. Add rows to the table, as needed.

<table>
<thead>
<tr>
<th>Course prefix and number (include cross-listings)</th>
<th>Units</th>
<th>Title</th>
<th>Course Description</th>
<th>Pre-requisites</th>
<th>Modes of delivery (online, in-person, hybrid)</th>
<th>Typically Offered (F, W, Sp, Su)</th>
<th>Dept signed party to proposal? (Yes/No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 105A</td>
<td>1</td>
<td>Introduction to Scientific Computing</td>
<td>The course provides an introduction to the use of computing in a scientific environment. The course objective is to introduce students to the C programming language as a tool for solving numerical problems. This course is prerequisite to PHYS 305.</td>
<td>Math 125/122B</td>
<td>In-person</td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
<tr>
<td>PHYS 161H</td>
<td>4</td>
<td>Honors Introductory Mechanics</td>
<td>A freshman-level course in Newtonian mechanics, taught at an accelerated level; introduces freshman-level students to the statics and dynamics of point particles, rigid bodies, and fluids. Topics include vector algebra, projectile and circular motion, Newton's Laws, conservation of energy, collisions and conservation of momentum, rotational dynamics and</td>
<td>MATH 122B, 124, or 125, or appropriate Math Placement Level. Honors active. $50 course fee</td>
<td>In-person</td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
<tr>
<td>Course Code</td>
<td>Units</td>
<td>Course Name</td>
<td>Description</td>
<td>Corequisites</td>
<td>Delivery Mode</td>
<td>Offered</td>
<td>Honors Active</td>
</tr>
<tr>
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</tr>
<tr>
<td>PHYS 162H</td>
<td>4</td>
<td>Honors Introductory Optics and Thermodynamics</td>
<td>A freshman-level course in the fundamental properties of light and heat, taught at an accelerated level; introduces students to the propagation of light and heat and related applications such as optical instruments and heat engines. Topics include temperature scales and heat, laws of thermodynamics, kinetic theory of gases and elementary statistical mechanics, heat engines, elementary wave theory and sound, light as an electromagnetic wave, geometrical optics, lenses and mirrors, physical optics, diffraction and interference, optical instruments.</td>
<td>(PHYS 141 or PHYS 140 or PHYS 161H, including transfer and AP credit) and (MATH 129 or MATH 250A or appropriate Math Placement Level, including transfer and AP credit). Honors active.</td>
<td>In-person</td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
<tr>
<td>PHYS 261H</td>
<td>4</td>
<td>Honors Introductory Electricity and Magnetism</td>
<td>A first course in electromagnetic fields and their applications. Coulomb’s and Gauss’ Law, electric fields and potentials, electrical and magnetic properties of matter, Ampere’s and Faraday’s laws, elementary DC and AC circuits, Maxwell’s equations. Methods of vector calculus are used extensively.</td>
<td>(PHYS 141 or PHYS 140 or PHYS 161H, including transfer and AP credit) and (MATH 129 or MATH 250A or appropriate Math Placement Level, including transfer and AP credit). Honors active.</td>
<td>In-person</td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
<tr>
<td>PHYS 263H</td>
<td>3</td>
<td>Honors Introductory</td>
<td>A first course in relativistic and quantum concepts developed in (PHYS 162H or 142 or 143) and prerequisite or concurrent enrollment in (PHYS 261H or PHYS 263H).</td>
<td>In-person</td>
<td>F/Sp</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Description</td>
<td>Prerequisites</td>
<td>Coreq.</td>
<td>Type</td>
<td>In-Person</td>
<td>F/Sp</td>
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</tr>
<tr>
<td>PHYS 204</td>
<td>Mathematical Techniques in Physics</td>
<td>Mathematical techniques used in upper division physics courses. Complex numbers, Taylor series, coordinate systems, elementary probability, Fourier series, Linear algebra, vector operators, partial differential equations.</td>
<td>MATH 223 and (PHYS 162H or 261H or 142 or 241 or 240 or 143). Prerequisite or concurrent registration in MATH 254 or MATH 355.</td>
<td></td>
<td></td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
<tr>
<td>PHYS 305</td>
<td>Computational Physics</td>
<td>Introduction to numerical techniques for solving physics problems. Introduction to a high-level programming language, numerical integration, finding roots, ordinary differential equations, least squares fitting. This course is a prerequisite for the following courses: PHYS332, PHYS426, PHYS472.</td>
<td>(PHYS 105A or ECE 175) and (PHYS 142 or 143 or 162H) and (PHYS 240 or 241 or 261H). Prerequisite or concurrent registration in MATH 254 or MATH 355.</td>
<td></td>
<td></td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
<tr>
<td>PHYS 321</td>
<td>Theoretical Mechanics</td>
<td>A mid-level course in classical mechanics using Newtonian, Lagrangian and Hamiltonian formulations. Motions studied include: simple, damped and forced harmonic oscillators, conservation laws and collisions, central forces, gravitation and planetary orbits,</td>
<td>(PHYS 142 or 143 or 162H) and (PHYS 240 or 241 or 261H) and MATH 223. Prerequisite or concurrent registration in PHYS 204 and (MATH 254 or MATH 355).</td>
<td></td>
<td></td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
</tbody>
</table>
rotation of rigid bodies. Non-inertial reference frames are examined. Vector calculus in curvilinear coordinates and in phase space are used.

**PHYS 331**  
3  
**Electricity & Magnetism I**  
The study of static electric and magnetic fields separately in vacuum and in matter leads to Maxwell’s equations, which relate electric and magnetic fields when time-dependence sets in. Vector calculus in curvilinear coordinates is an indispensable tool throughout the course.  
**(PHYS 240 or 241 or 261H) and MATH 223 and PHYS 204. Prerequisite or concurrent registration in PHYS 321.**  
In-person  
F/Sp  
Yes

**PHYS 371**  
3  
**Quantum Theory**  
A mid-level course starts with Schrödinger’s equation and waves applied to one particle in one-dimensional potential wells and ends with the hydrogen atom in three dimensions. Topics cover limits of classical physics, wave equations, phase and group velocities, Schroedinger’s equation, one dimensional problems - square well, step potentials, operators and matrices, observables and measurements, the uncertainly principle, the harmonic oscillator, raising and lowering operators, two particle problems, Schroedinger’s equation in three dimensions, angular momentum and the hydrogen atom. Partial differential equation and linear algebra are basic tools.  
**PHYS 321, PHYS 263H, and PHYS 204.**  
In-person  
F/Sp  
Yes
<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Description</th>
<th>Prerequisite or concurrent enrollment:</th>
<th>Offered In</th>
<th>Mode</th>
<th>Offered</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 381</td>
<td>2</td>
<td>Designed to develop experimental skills and to demonstrate important concepts in classical and modern physics by measuring fundamental physical constants, as well as the importance of error estimation and propagation. This is a Writing Emphasis Course to develop professional writing skills including notebook documentation and manuscript preparation.</td>
<td>PHYS 321 and (PHYS 305 or 320 or 331 or 371).</td>
<td>In-person</td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
<tr>
<td>PHYS 382</td>
<td>2</td>
<td>Continuation of PHYS 381 with a special project to be determined by the student and the instructor. This is a Writing Emphasis Course like PHYS 381.</td>
<td>PHYS 381.</td>
<td>In-person</td>
<td>F/Sp</td>
<td>Yes</td>
</tr>
<tr>
<td>ENGR 498A</td>
<td>3</td>
<td>Students will work in cross-disciplinary teams to solve industry-sponsored real-world design problems using the design process. Teaming, design process, design concept, design proposal. ENGR 498A and ENGR 498B must be taken in consecutive semesters. Usually offered in the Fall.</td>
<td>Consult the College of Engineering website at <a href="http://engr.arizona.edu/undergrad/engr498">http://engr.arizona.edu/undergrad/engr498</a> for specific course requisites for your engineering major.</td>
<td>In-person</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>ENGR 498B</td>
<td>3</td>
<td>Students will work in cross-disciplinary teams to solve industry-sponsored real-world design problems using the design process. Construction, testing and evaluation of prototype design; design iteration to arrive at a final working system. Major design</td>
<td>Adv Stdg: Engineering. Senior status and ENGR 498A</td>
<td>In-person</td>
<td>Sp</td>
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</tr>
<tr>
<td>Course Code</td>
<td>Units</td>
<td>Course Title</td>
<td>Description</td>
<td>Fee</td>
<td>Delivery</td>
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</tr>
<tr>
<td>COMM 119/PR 119</td>
<td>3</td>
<td>Public Speaking</td>
<td>This course is designed to help students become more comfortable with speaking in public, and to familiarize them with the theory-based, basic skills of public speaking. It will also help to increase students' communication, competence, and effectiveness, as well as improve capabilities in research, and critical thinking. This course will expose students to a variety of everyday speaking occasions.</td>
<td>$50</td>
<td>In-person</td>
<td></td>
</tr>
<tr>
<td>ENGL 308</td>
<td>3</td>
<td>Technical Writing</td>
<td>Analysis and presentation of scientific and technical information.</td>
<td></td>
<td>F/Sp/Su</td>
<td></td>
</tr>
<tr>
<td>ENGL 340</td>
<td>3</td>
<td>Topics in Professional and Technical Writing</td>
<td>An advanced topics course on professional and technical writing</td>
<td></td>
<td>In-person</td>
<td></td>
</tr>
<tr>
<td>JOUR 472</td>
<td>3</td>
<td>Science Journalism</td>
<td>Science is one of the most powerful forces of change in the world. This applied course covers the fundamental elements of producing news reports about science events and issues. We will examine the principles of journalism, the scientific process and the differences between science journalism and science communication. Guest speakers, prominent science journalists and scientists will</td>
<td></td>
<td>In-person</td>
<td></td>
</tr>
</tbody>
</table>
explore key issues involved in communicating with the public about science. Readings, case studies and discussions will examine issues of balance, scientific uncertainty, accuracy and ethical codes for science journalists.

You'll write professional-quality science articles for general interest and specialized news media. You'll learn how to gather, evaluate and organize information in ways that will produce accurate, comprehensive information for the public. Each student will write one short piece, and in pairs you'll research and produce an in-depth article.

| JOUR 455 | 3 | Environmental Journalism | This applied course teaches you to write compelling, substantive stories that illuminate environmental subjects, trends and issues, often in human terms. This course emphasizes the role of the environmental journalist not as an advocate but as a reporter who accurately and fairly reports the news. We examine the principles of journalism, the scientific process and the differences between environmental journalism and environmental communication. Guest speakers - journalists, | $50 course fee | In-person | Sp |
researchers and other experts - explore key issues involved in communicating with the public about the environment. Readings and discussions examine issues of balance, scientific uncertainty, risk, accuracy and ethical codes.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Units</th>
<th>Course Title</th>
<th>Description</th>
<th>Prerequisites</th>
<th>Delivery</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISTA 311</td>
<td>3</td>
<td>Foundation of Information and Inference</td>
<td>An introduction to the mathematical theories of probability and information as tools for inference, decision-making, and efficient communication. Topics include discrete and continuous random variables, measures of information and uncertainty, discrete time/discrete state Markov chains, elements of Bayesian inference and decision-making, Bayesian and Maximum Likelihood parameter estimation, and elementary coding theory.</td>
<td>(ISTA 116 or MATH 163 or MATH 263) and (ISTA 130 or CSC 110) or Consent of instructor.</td>
<td>Hybrid</td>
<td>F</td>
</tr>
<tr>
<td>ISTA 350</td>
<td>4</td>
<td>Programming for Informatics</td>
<td>This course will provide an introduction to informatics application programming using the python programming language and applying statistical concepts from a first semester statistics course. A key goal of this course is to prepare students for upper division ISTA courses by expanding on the skills gained in ISTA 116 and 130 but will be broadly applicable to any informatics discipline. Throughout the semester ISTA 116 or ISTA 120 or ISTA 130 or ISTA 131 or equivalent, or consent of instructor.</td>
<td>$50 course fee</td>
<td>Hybrid</td>
<td>Sp</td>
</tr>
</tbody>
</table>
students will be faced with information application problems drawn from several different disciplines in order to expand their breadth of experience while simultaneously increasing their depth of knowledge of scientific and informatics programming methods. Students will practice problem decomposition and abstraction, gaining experience in identifying commonly occurring information processing issues and in applying well-known solutions. In addition, students will design their own algorithmic solutions to problems and will learn how to effectively compare different solutions, evaluating efficiency in order to choose the best solution for a given problem. Periodic code reviews will be held in order to expose students to a range of different solution methods, which will aid them in discovering weaknesses in their own work and will improve their ability to communicate with others on technical topics. The course will include an introduction to the python scientific computing libraries and other statistical packages. Additional course topics will include the use of version control systems, software
<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Title</th>
<th>Description</th>
<th>Requirements</th>
<th>Fee</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISTA 421</td>
<td>3</td>
<td>Introduction to Machine Learning</td>
<td>Machine learning describes algorithms which can modify their internal parameters (i.e., &quot;learn&quot;) to recognize patterns and make decisions based on examples or through interaction with the environment. This course will introduce the fundamentals of machine learning, will describe how to implement several practical methods for pattern recognition, feature selection, clustering, and decision making for reward maximization, and will provide a foundation for the development of new machine learning algorithms.</td>
<td>ISTA 311, MATH 129, and MATH 313, or equivalent, or consent of instructor. ISTA 116 or comparable is recommended. $50 course fee</td>
<td>In-person</td>
<td>F</td>
</tr>
<tr>
<td>MATH 263</td>
<td>3</td>
<td>Introduction to Statistics and Biostatistics</td>
<td>Organizing data; distributions, measures of center and spread, scatterplots, nonlinear models and transformations, correlation, regression. Design of experiments: models from probability, discrete and continuous random variables, normal distributions, sampling distributions, the central limit theorem. Statistical inference; confidence intervals and test of significance, t procedures, inference for count data, two-way tables and chi-square procedures, inference for</td>
<td>PPL 60+ or MCLG 88+ or SAT I MSS 620+ or ACT MATH 26+ or one recent course from MATH 112, 113, 116, 122B, or 125. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112 first. $50 course fee</td>
<td>Hybrid</td>
<td>F/Sp/Su</td>
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<tr>
<td>regression, analysis of variance.</td>
<td>Examinations are proctored.</td>
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</tr>
</tbody>
</table>
IV. **NEW COURSES NEEDED** – using the table below, list any new courses that must be created to initiate the major. If specific course number is undetermined, please provide level, (ie CHEM 4**). Add rows as needed. Is a new prefix needed? If so, provide the subject description so Curricular Affairs can generate proposed prefix options.

<table>
<thead>
<tr>
<th>Course prefix and number (include cross-listings)</th>
<th>Units</th>
<th>Title</th>
<th>Course Description</th>
<th>Pre-requisites</th>
<th>Modes of delivery (online, in-person, hybrid)</th>
<th>Status*</th>
<th>Anticipated first term offered</th>
<th>Typically Offered (F, W, Sp, Su)</th>
<th>Dept signed party to proposal? (Yes/No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO NEW COURSES NEEDED</td>
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</tr>
</tbody>
</table>

*In development (D); submitted for approval (S); approved (A)*

Subject description for new prefix (if requested). Include your requested prefix, if any. :
V. **FOUR-YEAR PLAN** – provide a sample four-year degree plan that includes all requirements to graduate with this major and takes into consideration course offerings and sequencing. Refer to [Degree Search](#) for examples. Use generic title/placeholder for requirements with more than one course option (e.g. Upper Division Major Elective, Minor Course, Second Language, GE Tier 1, GE Tier 2). Add rows as needed.

<table>
<thead>
<tr>
<th>Semester 1</th>
<th>Semester 2</th>
<th>Semester 3</th>
<th>Semester 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course prefix and number</td>
<td>Units</td>
<td>Course prefix and number</td>
<td>Units</td>
</tr>
<tr>
<td>MATH 122A/B or 125</td>
<td>5/3</td>
<td>MATH 129</td>
<td>3</td>
</tr>
<tr>
<td>ENGL 101/107 or 109H</td>
<td>3</td>
<td>PHYS 161H</td>
<td>4</td>
</tr>
<tr>
<td>GE Tier 1</td>
<td>3</td>
<td>ENGL 102/108</td>
<td>3</td>
</tr>
<tr>
<td>GE Tier 1</td>
<td>3</td>
<td>GE Tier 1</td>
<td>3</td>
</tr>
<tr>
<td>Second Language</td>
<td>3/5</td>
<td>Second Language</td>
<td>3/5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>15/19</td>
<td><strong>Total</strong></td>
<td>16/18</td>
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<table>
<thead>
<tr>
<th>Semester 5</th>
<th>Semester 6</th>
<th>Semester 7</th>
<th>Semester 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course prefix and number</td>
<td>Units</td>
<td>Course prefix and number</td>
<td>Units</td>
</tr>
<tr>
<td>PHYS 305</td>
<td>3</td>
<td>PHYS 371</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 321</td>
<td>3</td>
<td>PHYS 381</td>
<td>2</td>
</tr>
<tr>
<td>PHYS 331</td>
<td>3</td>
<td>Technical Elective #2</td>
<td>3</td>
</tr>
<tr>
<td>Technical Elective #1</td>
<td>3</td>
<td>Technical Elective #3</td>
<td>3</td>
</tr>
<tr>
<td>GE Tier 2</td>
<td>3</td>
<td>GE Tier 2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>15</td>
<td><strong>Total</strong></td>
<td>14</td>
</tr>
</tbody>
</table>
VI. **STUDENT LEARNING OUTCOMES AND CURRICULUM MAP**—describe what students should know, understand, and/or be able to do at the conclusion of this major. Work with [Office of Instruction and Assessment](#) to create a curricular map using Taskstream. Include your curricular map in this section (refer to Appendix B for sample Curriculum Map).

---

### BS Applied Physics

Courses and Activities Mapped to BS Applied Physics Outcome Set

<table>
<thead>
<tr>
<th>Course/Outcome</th>
<th>Communication</th>
<th>Experiment Design</th>
<th>Curriculum</th>
<th>Mathematical/Computation Skills</th>
<th>Multidisciplinarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core-Physics Knowledge: Coh knowledge that form the basis of classical mechanics, quantum mechanics, electromagnetism, optics and thermodynamics.</td>
<td>Co</td>
<td>Ex</td>
<td>Cu</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Experiment Design: Design, conduct and analyze experiments to optimize engineering design solutions to investigate underlying physical phenomena.</td>
<td>Ex</td>
<td>Ex</td>
<td>Cu</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Communication: Ability to communicate experimental results and to present engineering design solutions in written and oral form.</td>
<td>Cu</td>
<td>Cu</td>
<td>Cu</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Mathematical/Computation Skills: Proficiency in using mathematical or computational stratics to investigate physical phenomena or to optimize solutions to technological problems.</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Multidisciplinarity: Ability to work in multidisciplinary teams to address technological problems arising in academic, government or private sectors.</td>
<td>Mu</td>
<td>Mu</td>
<td>Mu</td>
<td>Mu</td>
<td>Mu</td>
</tr>
</tbody>
</table>

**Courses and Learning Activities**

<table>
<thead>
<tr>
<th>Course/Outcome</th>
<th>Communication</th>
<th>Experiment Design</th>
<th>Curriculum</th>
<th>Mathematical/Computation Skills</th>
<th>Multidisciplinarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intro Physics</td>
<td>Co</td>
<td>Ex</td>
<td>Cu</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Advanced Physics Courses</td>
<td>Co</td>
<td>Ex</td>
<td>Cu</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Core-Physics Knowledge: Coh knowledge that form the basis of classical mechanics, quantum mechanics, electromagnetism, optics and thermodynamics.</td>
<td>Co</td>
<td>Ex</td>
<td>Cu</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Experiment Design: Design, conduct and analyze experiments to optimize engineering design solutions to investigate underlying physical phenomena.</td>
<td>Ex</td>
<td>Ex</td>
<td>Cu</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Communication: Ability to communicate experimental results and to present engineering design solutions in written and oral form.</td>
<td>Cu</td>
<td>Cu</td>
<td>Cu</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Mathematical/Computation Skills: Proficiency in using mathematical or computational stratics to investigate physical phenomena or to optimize solutions to technological problems.</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Mu</td>
</tr>
<tr>
<td>Multidisciplinarity: Ability to work in multidisciplinary teams to address technological problems arising in academic, government or private sectors.</td>
<td>Mu</td>
<td>Mu</td>
<td>Mu</td>
<td>Mu</td>
<td>Mu</td>
</tr>
</tbody>
</table>

**Curriculum Map:**

---
VII. ASSESSMENT PLAN FOR STUDENT LEARNING- using the table below, provide a schedule for program assessment of intended student learning outcomes 1) while students are in the program and 2) after completion of the major. Add rows as needed. Delete EXAMPLE row.

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
<th>Sources(s) of Evidence</th>
<th>Assessment Measures</th>
<th>Data Collection Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>In program. Core knowledge that form the basis of classical mechanics, quantum mechanics, electromagnetism, optics and thermodynamics</td>
<td>Course-embedded assessments</td>
<td>Exams, laboratory reports, and other forms of student work (projects).</td>
<td>Throughout and by end of each course</td>
</tr>
<tr>
<td>In program. Design and conduct experiments to investigate physical phenomena; document, analyze, interpret and communicate results in written and oral form.</td>
<td>Course-embedded assessments</td>
<td>laboratory notebook, laboratory report, report in journal format, oral presentations.</td>
<td>Throughout and by end of each course</td>
</tr>
<tr>
<td>In program. Proficiency in using mathematical or computational skills to investigate physical phenomena or optimize solutions to technological problems</td>
<td>Course-embedded assessments</td>
<td>Exams, and other forms of student work (e.g. compute code)</td>
<td>Throughout and by end of each course</td>
</tr>
<tr>
<td>In program. Ability to work in multidisciplinary teams to address technological problems arising in academic, govt. or private sectors</td>
<td>Course-embedded assessments</td>
<td>Student projects</td>
<td>End of each course</td>
</tr>
<tr>
<td>After program completion. Preparedness to assume challenging technical positions in a variety of industries, or to continue study in technical fields</td>
<td>Program exit survey, Alumni survey, Professional media presence (LinkedIn)</td>
<td>Employment status, position</td>
<td>Annual</td>
</tr>
</tbody>
</table>
VIII. **PROGRAM ASSESSMENT PLAN** - using the table below, provide a schedule for program evaluation 1) while students are in the program and 2) after completion of the major. Add rows as needed. Delete **EXAMPLE** rows.

<table>
<thead>
<tr>
<th>Assessment Measure</th>
<th>Source(s) of Evidence</th>
<th>Data Collection Point(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>In program.</em> Student retention</td>
<td>Enrollment statistics, student survey</td>
<td>Start of each semester</td>
</tr>
<tr>
<td><em>After program completion.</em> Job Placement Statistics</td>
<td>Student/Alumni Survey, LinkedIn data mining</td>
<td>At graduation, and annual</td>
</tr>
<tr>
<td>Professional advisory board review: board consisting mostly of applied physics and physics alumni, along with industry representatives</td>
<td>Board review report</td>
<td>Every 2 years</td>
</tr>
<tr>
<td>Academic Program Review (APR)</td>
<td>Report from the external APR committee</td>
<td>Every 7 years</td>
</tr>
</tbody>
</table>
IX. **NEED FOR THE MAJOR**—describe how the major fulfills the needs of the city, state, region, and nation. Provide market analysis data or other tangible evidence of the need for and interest in the proposed major. This might include results from surveys of current students, alumni, and/or employers or reference to student enrollments in similar programs in the state or region. Include an assessment of the employment opportunities for graduates of the program during the next three years.

The Bureau of Labor Statistics (BLS) projects a 15% national increase in the employment of physicists over the decade 2016-26, with the need being particularly acute in “research and development in engineering and life sciences” (29% increase) and in “management and technical consulting” (25% increase).* By comparison, the projected national increase in university and government employment is relatively mild (6%). For the state of Arizona, the Office of Economic Opportunity projects an increase of 6,200 engineering jobs over the same time frame, compared to around 100-300 jobs for physics-related fields.** These indicate a growing economic need for physics graduates locally and nationally, with the need being particularly acute in engineering, biomedical, business and other areas outside the traditional academic track for physics.

** [https://laborstats.az.gov/employment-forecasts](https://laborstats.az.gov/employment-forecasts)

The UA Department of Physics graduates 20-25 physics majors every year, a number that has been flat over the last decade. Exit surveys have determined that 45-50% of our majors enroll in graduate school, slightly below the national average of 54%.*** Over half our graduates end up on a so-called “nontraditional” track, mostly in private-sector jobs in engineering, information technology or biomedical fields. A traditional physics education does not explicitly train students in the kinds of skills these environments require, such as team-based problem solving, statistical analysis, project management and presentation skills. Alumni interviews have revealed a significant gap in preparation for the majority of our alumni headed for the private sector (whereas PhD-bound alumni have been highly satisfied with their preparation for grad school). The most commonly reported gap was their lack of training in working with multidisciplinary teams, followed by lack of exposure to data mining skills and communication/outreach. This is in complete agreement with the shortfalls identified by the American Institute of Physics “J-TUPP” Report (Joint Task Force on Undergraduate Physics Programs). A few relevant slides from the J-TUPP report are appended at the end of this section.


The labor projections, together with the current status of the physics major, show the need for increasing the numbers of Department of Physics graduates and for training a large subset explicitly for work in the private sector. The proposed Applied Physics major satisfies both of these requirements. Around one-third of US universities offer an Applied Physics degree in addition
to a (Comprehensive) Physics degree, including designated peer institutions such as UC Davis and University of Washington. Applied Physics majors comprise 53% of the undergraduate physics population at Washington and 39% at UC Davis. The comparable numbers of applied physics vs. physics majors at peer institutions justify the feasibility and the need for two separate programs.

Surveys administered to our own physics and engineering students (appended to the proposal) have shown that Applied Physics will be a strong and viable major, with around 150 to 200 students at maturity. The surveys indicate a conversion rate of about 20% of current physics majors to applied physics, which will not endanger the traditional Physics major. As the two programs mature together, we anticipate similar numbers in both, consistent with the experience of peer institutions. The NET gain to the College of Science (not counting the conversions from physics) is anticipated to be 110 to 160 students at maturity (Year 6).

Most of these students might have otherwise left the university or might have initially chosen engineering or similar applied disciplines. For the latter category, as long as the College of Engineering, Optical Sciences etc. meet their enrollment goals for new student numbers, the majors in Applied Physics should represent new students to the University of Arizona.

While Applied Physics programs are becoming increasingly common at peer institutions, they are still uncommon among universities in the Southwest, creating a timely opportunity to attract students to the University of Arizona. While an Applied Physics major does exist at an ASU satellite campus, its enrollment numbers are low (22), and it is focused on areas relevant to the semiconductor industry. Here we propose a broader and more flexible program, which students (under close advising) can direct toward careers in information technology, life sciences, military, or other engineering careers.

As discussed in the budget section, additional personnel required for the increased demand for lectures, lab sections, grading and research mentoring are offset by RCM returns to the college, so the department can handle the inflow of new students.

We anticipate that employer “call-outs” for Applied Physics majors will be similar to that for non-academic Physics majors, but Applied Physics majors will be better prepared for the interview and selection process, for several reasons. First, preparation for the private sector is part of the national “brand” for applied physics among industries looking for graduates with broad-based problem-solving. Second, the soft-skills training in project management, communication, etc., will enable Applied Physics majors to market themselves more effectively. Third, the specific networks they form with local and state industry during their engineering design project will give them solid leads to internships and job opportunities.
Although Applied Physics emphasizes preparation for the private sector, we expect that a small minority will also end up in other sectors such as government or public policy, law, career military, and primary or secondary education. The broad exposure and soft skills that Applied Physics majors absorb will be useful here as well, since these sectors often emphasize project-based teamwork in the context of technical expertise. In the education field in particular, we anticipate that applied physics majors will have the expertise to teach both science and engineering classes, which are often taught separately in public school districts.

There is ample precedent for proposing a separate BS in Applied Physics administered by the department of physics, since about half the universities that offer applied physics do so in this form (including our peers UC Davis and U of Iowa). This fits the UA institutional tradition of separate BS degrees in Astronomy, Atmospheric Science, Optical Science and the like, which are often classified as “physics” at other institutions. It is a recognition that these majors prepare students for qualitatively distinct career paths, even when (as in the case of Astronomy) the degree of overlap with physics is similar to that of Applied Physics. The BS in Applied Physics would allow the department to market the new major with other Applied Physics degrees, giving it national visibility. And the disestablishment of the unproductive BA degree creates administrative room to implement the new BS (memo appended).

Finally, during the drafting of this proposal, the department became aware of an opportunity to form a Joint College with Hebei University of Technology (HEBUT) in Tianjin, China, who are highly interested in operating a dual degree program in Applied Physics with the UA. While this interesting opportunity is currently at the exploratory stage, the proposed scale is 120 students per year for Applied Physics, starting in Fall 2019. We hope that this proposal can be considered in an expedited fashion to take advantage of this potential opportunity.

To conclude, we append three relevant slides from the AIP’s Joint Taskforce on Undergraduate Physics Programming (J-TUPP) Report. The report was the synthesis of many studies and questionnaires conducted by the American Institute of Physics. The Applied Physics program is designed specifically to address the shortfalls identified in this report, without sacrificing the excellent graduate school preparation that the department offers to traditional Physics majors.
A FEW FACTS

- 7500 people graduate with bachelor’s degrees in physics each year
- 350 people are hired as physics faculty members each year
- 5% of all physics bachelor’s eventually end up as physics professors
- 40% of bachelor’s graduates enter the workforce immediately
  - 61% work in the private sector
  - 13% work in colleges and universities
  - 8% work in high schools
  - 6% work in the military
  - 5% work in civilian government or national laboratories
- 35% of physics PhD holders work in 4-year academic institutions

Various reports, AIP Statistical Research Center

IS THERE A PROBLEM?

Most departments prepare students primarily for academic careers and do not do anything special to prepare students for other paths.

Tacit assumption: the skills and knowledge needed for those careers develop “automatically.”

In spite of this lack of attention, physics graduates are successful in a wide variety of careers (including academia).

However,
Many graduates and their employers report that they were unprepared in several key areas
Graduates in related disciplines are better prepared to compete for jobs

Various reports, AIP Statistical Research Center

WHAT DO EMPLOYERS WANT?

1. The ability to work well in teams—especially with people different from oneself
2. An understanding of science and technology and how they are used in real-world settings
3. The ability to write and speak well
4. The ability to think clearly about complex problems
5. The ability to analyze a problem to develop workable solutions
6. An understanding of global context in which work is now done
7. The ability to be creative and innovative in solving problems
8. The ability to apply knowledge and skills in new settings
9. The ability to understand numbers and statistics
10. A strong sense of ethics and integrity
11. Ability to make decisions and solve problems
12. Ability to sell or influence others
13. Ability to plan, organize and prioritize work
X. **ANTICIPATED STUDENT ENROLLMENT** - complete the table below. What concrete evidence/data was used to arrive at the numbers?

<table>
<thead>
<tr>
<th>5-YEAR PROJECTED ANNUAL ENROLLMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Students</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
<th>5th Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low: 12</td>
<td>Low: 36</td>
<td>Low: 68</td>
<td>Low: 93</td>
<td>Low: 109</td>
<td></td>
</tr>
<tr>
<td>High: 30</td>
<td>High: 66</td>
<td>High: 102</td>
<td>High: 134</td>
<td>High: 150</td>
<td></td>
</tr>
</tbody>
</table>

6th Year: Low 116, High 158
Data/evidence used to determine projected enrollment numbers:

The table lists low and high projections for the NET number of new majors added to Department of Physics, i.e., it does NOT count internal conversions from (Comprehensive) Physics to Applied Physics. (For the total number of Applied Physics majors, add about 10 to 15 students per year, starting with Year 2.) These numbers were determined from interpreting student survey data, administered in person across seven different courses in Spring 2018, from large engineering survey courses to smaller upper-division physics courses. (The questionnaire and raw survey results have been appended.) Students were given a short, neutral 5-minute description of the proposed major, which was also reproduced on the survey form. The presenter answered any student questions (usually there were two or three), and students were asked to fill out the anonymous survey and return it to the instructor at the end of class. Surveys asked each student to list her/his major and year and answer the following key question:

“Think back to when you were an entering Freshman shopping for majors. If Applied Physics had been one of the options, how likely would you have been to choose it as a major, instead of your current major? Use the following scale: 1 = very likely, 2 = somewhat likely, 3 = not sure, 4 = probably not, 5 = definitely not.”

The presenter emphasized to the class that the only “right answer” to this question was the student’s honest answer, and the department had no interest in starting a new major if there was no demand.

The responses indicated conversion rates of 20% from current Physics majors and 5%-7% from engineering majors, once the program reaches maturity. The weightings were relatively conservative: “1” responses were given a conversion probability of 0.6 to 0.7, “2” responses were given a probability of 0.3 to 0.4, and all other responses were given zero probability. In the above table, the “Low” numbers assume 5% conversion from engineering, and the “High” numbers assume 7% conversion.
This model for student enrollment projections (also used in the budget projections) makes the following assumptions to make it more realistic:

1. The *incoming* Applied Physics number reaches saturation at Year 3. (Years 1 and 2 are the recruitment and ramp-up phase.) Therefore the *total* number reaches saturation at Year 6, as the first “full” incoming class reaches graduation.

2. 80% of each incoming class are Freshmen, 20% are transferring Juniors (based on current demographics in Physics).

3. Each incoming class is propagated through their 4 years (for Freshmen) or 2 years (for transfers), assuming a 10% average year-to-year attrition. (Average year-to-year attrition for Physics majors currently is around 15%, and retention is expected to be higher for Applied Physics since fewer upper-division physics courses are required.)

4. For this model, we assume incoming Freshmen take 4 years to complete, and incoming Juniors take 2 years. A significant minority of physics students take 4.5 or 5 years to complete, so the projections may be slightly more spread-out than shown.

XI. ANTICIPATED DEGREES AWARDED—complete the table below, beginning with the first year in which degrees will be awarded. How did you arrive at these numbers? Use National Center for Education Statistics College Navigator to find program completion information of peer institutions offering a same or similar major.

<table>
<thead>
<tr>
<th>PROJECTED DEGREES AWARDED ANNUALLY</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
<th>5th Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Degrees</td>
<td>Low: 0</td>
<td>Low: 7</td>
<td>Low: 12</td>
<td>Low: 16</td>
<td>Low: 21</td>
</tr>
<tr>
<td></td>
<td>High: 5</td>
<td>High: 15</td>
<td>High: 20</td>
<td>High: 26</td>
<td>High: 29</td>
</tr>
</tbody>
</table>

6th Year: Low 28, High 37

These numbers are based on the same survey data and model assumptions used in Section X. In particular, we assume an average 10% year-to-year attrition for a given Applied Physics cohort, based on current 15% attrition rates of our current physics undergraduates. As stated elsewhere, applied physics attrition rates are expected to be lower, since it replaces several difficult upper-division physics courses with courses of greater practical value in the private sector.
XII. **PROGRAM DEVELOPMENT TIMELINE**- describe plans and timelines for 1) marketing the major and 2) student recruitment activities.

We will recruit Applied Physics majors from four distinct student populations, each with slightly different needs and interests: Current physics majors, transfer students from Pima Community College, high school seniors interested in physics, and high school seniors interested in engineering. For ALL of these groups, the first step will be to advertise the newly approved Applied Physics major prominently on the department website, and upload the major requirements, target careers and sample 4-year plans.

*Current physics majors.* Upon approval, we will immediately announce the new major at all levels of courses for physics majors. Our undergraduate advisor, Holly Brown, has played a leading role in the creation of this proposal and is intimately familiar with the four-year academic plan, so that advising can begin immediately after approval. A trifold pamphlet will be designed for Applied Physics (based closely on the current one for physics) and distributed to all current undergrads.

*Transfer students from PCC.* One of the physics faculty (Srin Manne) currently heads a physics summer bridge program for PCC transfer students and has developed strong working relationships with several PCC faculty, including Karie Meyers (physics), Alexander Shayevich (engineering), Sylvia Kolchens (chemistry) and Padma Nair (biology). These faculty have enthusiastically agreed to recruiting presentations given to their classes, in which Applied Physics can be marketed to PCC students along with the summer bridge program. We believe this will be a significant source of new majors in Years 1 and 2 especially.

*High school seniors interested in physics.* The departmental new student orientation program receives virtually universal attendance from incoming physics majors each year. Marketing and advising for Applied Physics will be carried out at the same level as for (Comprehensive) Physics at each orientation event. The AP and CP students have almost identical schedules in the first 3 semesters, bifurcating in the 4th semester. During the introductory physics courses and during Freshman and Sophomore advising sessions, students will be prompted to consider their career interests and sort themselves into AP and CP by semester 4 or 5.
High school seniors interested in engineering. Anecdotal experience among physics faculty has shown that a small but significant minority of high school students who love physics, nevertheless choose an engineering major as the more practical option for a private-sector career. This view is particularly prevalent among underrepresented minorities and those from family backgrounds with limited tertiary education, for whom employment is an overriding concern. For these populations (an estimated 5%-7% of engineering students from our student surveys), we will market the Applied Physics option at large local high schools, through contact with their physics and engineering clubs and/or teachers. This activity will begin in December of Year 1 and continue through Years 2 and 3, until the “incoming” numbers reach maturity.
XIII. DIVERSITY AND INCLUSION—describe how you will recruit diverse students and faculty to this program.

Faculty experience with the PCC summer bridge program and with recruitment events at SACNAS (Society for Advancement of Chicano and Native American Scientists) show that a significant minority of students who love physics, nevertheless choose an engineering major as the more practical option for a private-sector career. This view is particularly prevalent among underrepresented minorities and those from family backgrounds with limited tertiary education. We believe that the non-academic career orientation of Applied Physics, together with the soft skills and networking opportunities it affords, will prove strongly attractive to students from underrepresented minorities.

The department will make a strong effort to market the new program in national minority-science organizations such as SACNAS and in regional meetings such as the Four Corners Chapter of the American Physical Society. The uniqueness of the Applied Physics major among universities in the Southwest should prove a draw for a diverse body of potential students.
XIV. **ABOR REQUIREMENT: Table-Proposed New Programs**

<table>
<thead>
<tr>
<th>Name of Proposed Degree (degree type and major), College/School, Location, Anticipated Catalog Year</th>
<th>Program Fee Required? (Yes or No)</th>
<th>Brief Description</th>
<th>Justification and Identified Market Need</th>
<th>Learning Outcomes and Assessment Plan</th>
<th>Projected 3rd Year Enrollment</th>
</tr>
</thead>
</table>
| Bachelor of Science in Applied Physics Department of Physics, College of Science, University of Arizona, Tucson AZ Beginning Fall 2019 | No | Description: A modified physics major emphasizing technical and collaborative skills relevant to industry | Justification: Many current physics graduates pursue careers in the private sector, for which they receive no explicit training in interdisciplinary teamwork and communication. Many high school students interested in physics see it as an impractical route to careers in the private sector. | Learning Outcome #1

**Concepts (Knowledge)**
Core theories of classical mechanics, statistical mechanics, quantum mechanics, electricity and magnetism

**Competencies (Skills)**
Ability to solve problems and make predictions based on theory

**Measures**
Periodic grading and feedback to students

**Assessment Method and/or Instrument(s)**
Problem sets, lab reports, exams and other forms of student work | Learning Outcome #2

**Concepts (Knowledge)**

By Year 3: Low est. 78 High est. 112
<table>
<thead>
<tr>
<th>Competencies (Skills)</th>
<th>Ability to set up and troubleshoot experimental apparatus and use it to measure and analyze data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures</td>
<td>Periodic grading and feedback to students</td>
</tr>
<tr>
<td>Assessment Method and/or Instrument(s)</td>
<td>Lab notebooks, lab reports and other forms of student work</td>
</tr>
</tbody>
</table>

**Learning Outcome #3**

<table>
<thead>
<tr>
<th>Concepts (Knowledge)</th>
<th>Knowledge of relevant programming languages and mathematical operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competencies (Skills)</td>
<td>Proficiency in using mathematical or computational skills to explore physical phenomena or optimal engineering design problems</td>
</tr>
<tr>
<td>Measures</td>
<td></td>
</tr>
<tr>
<td>Learning Outcome #4</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Concepts (Knowledge)</strong></td>
<td></td>
</tr>
<tr>
<td>Oral and written scientific communication in a multidisciplinary setting</td>
<td></td>
</tr>
<tr>
<td><strong>Competencies (Skills)</strong></td>
<td></td>
</tr>
<tr>
<td>Ability to present scientific results and engineering solutions to scientific and lay public audiences</td>
<td></td>
</tr>
<tr>
<td><strong>Measures</strong></td>
<td></td>
</tr>
<tr>
<td>Periodic grading and feedback to students</td>
<td></td>
</tr>
<tr>
<td><strong>Assessment Method and/or Instrument(s)</strong></td>
<td></td>
</tr>
<tr>
<td>Talks, posters, multidisciplinary group meetings and other forms of student work</td>
<td></td>
</tr>
<tr>
<td>Program name, subplan name (if applicable), degree, and institution</td>
<td>Proposed UA Program: Applied Physics, BS</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Current # of enrolled students</td>
<td>191 total in 2017-18</td>
</tr>
</tbody>
</table>
| Description of major | The major emphasizes 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.  

Applied Physics 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. This group will be distinct from traditional Physics majors. Applied Physics majors will replace 18 units of upper-division physics coursework with a combination of courses. |
| --- | --- |
| The Applied Track is aimed at students who plan to enter a technical job with their physics B.S. This is the most common track for students who arrived at UW thinking they were interested in engineering, but who decided to get a broader grounding in the physics underlying engineering before going on the job market. This track has fewer required courses to allow students to broaden their skills and knowledge sets in areas such as climate science, data science, programming, electrical engineering, aerospace, or entrepreneurship, and it is relatively straightforward to build a double major. The unique requirements of the Applied Track include a laboratory with a focus on statistics and error analysis, as well as a computer programming class relevant to data analysis.  

Note: UW is on the quarter system and requires 180 qtr. units to graduate. Multiply the quarter unit requirements in the UC Davis catalog by 4. |
| The major combines the principles of physics with practical expertise in one of seven specialties: atmospheric physics, chemical physics, computational physics, geophysics, materials science, physical electronics or physical oceanography. For example, a degree in applied physics with a computational physics specialty gives you a background in programming and allows you to approach problems through computation, an important skill as technology spreads increasingly throughout modern life.  

A UC Davis degree in applied physics provides you with a flexible set of skills preparing you for outstanding career opportunities in such areas as scientific computing, physics research (in academic, national and industrial laboratories); interdisciplinary fields involving physics, physical electronics or physical oceanography.  

Excerpts from:  
https://www.ucdavis.edu/majors/applied-physics/ |
| The acceleration of advances at the frontier between physics, engineering and technology creates a need for interdisciplinary training and research that is not readily accommodated by traditional single-focus programs in physics. Bringing fundamental physics together with its immediate applications, the BS in applied physics will be attractive to students whose interests span new physical technologies in industry and engineering. The degree combines physics, computer science and applied mathematics to tackle complex real-life problems in physics, material sciences, engineering, chemistry and others.  

The bachelor's degree program brings together the expertise of physics faculty, particularly in the modeling of |
in statistics and scientific communication, technical electives focused on the student’s career interests, and a year-long engineering design project (ENGR 498A and B) working with a mixed group of students from other science and engineering fields.

2/3 to compare to UA semester units.

Note: UC Davis is on the quarter system. In the unit comparisons, multiply the quarter unit requirements in the UC Davis catalog by 2/3 to compare to UA semester units.

<table>
<thead>
<tr>
<th>Target careers</th>
<th>Data science and information technology</th>
<th>-Climate Science</th>
<th>-Data Science</th>
<th>Programming and information technology</th>
<th>-Scientific computing</th>
<th>-High-performance and Scientific Computing</th>
<th>Biophysics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>Requirement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>---------------------------------------------------------------</td>
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<tr>
<td>Private-sector research and development</td>
<td>- Programming</td>
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<tr>
<td></td>
<td>- Electrical Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Aerospace Engineering</td>
<td></td>
<td></td>
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<td>- Entrepreneurship</td>
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<td>Business and entrepreneurship</td>
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<td>MAT 267 (3) Calculus for Engineers III</td>
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<td></td>
<td>PHY 201 (3) Mathematical Methods in Physics I</td>
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<td>PHY 302 (3) Mathematical Methods in Physics II</td>
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<td>Choice of Applied Physics Electives:</td>
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<td>MAT 343 Applied Linear Algebra</td>
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<td></td>
<td>PHY 321 Vector Mechanics and Vibration</td>
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<td></td>
<td>STP 420 Introductory Applied Statistics</td>
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<thead>
<tr>
<th>General education requirements</th>
<th>2 courses/ 6 units- Tier 1 150 (INDV)</th>
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<tbody>
<tr>
<td>Areas of Knowledge (chosen from Visual, Literary &amp; Performing Arts, Individuals &amp; Societies, Natural World)</td>
<td>21.3 equivalent units from arts, humanities and social sciences.</td>
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<tr>
<td>General Studies Core Requirements:</td>
<td>General Studies Core Requirements:</td>
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<tr>
<td>Pre-major? (yes/no)</td>
<td>No</td>
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<tr>
<td>2 courses/ 6 units-Tier I 160 (TRAD)</td>
<td>Basic Skills (Chosen from English composition and writing, Quantitative and Symbolic Reasoning, Foreign Language, Diversity)</td>
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<tr>
<td>3 units-Tier II Arts</td>
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<tr>
<td>1 course/ 3 units-Tier II Humanities</td>
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<tr>
<td>1 course/ 3 units-Tier II Individuals and Societies</td>
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<tr>
<td>+ 1 course with diversity emphasis</td>
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<td>[Total 50-90 credits]</td>
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| | | | General Studies Awareness Requirements:
<p>| | | | Cultural Diversity in the U.S. (C) |
| | | | Global Awareness (G) |
| | | | Historical Awareness (H) |
| | | | First-Year Composition |</p>
<table>
<thead>
<tr>
<th>Major requirements</th>
<th>None</th>
<th>None</th>
<th>None</th>
<th>none</th>
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<tbody>
<tr>
<td>Minimum # of units required in major</td>
<td>59 units</td>
<td>60 semester units (from 90 qtr u)</td>
<td>Total 56.7 to 70 equivalent semester units, depending on concentration. Approx. 70% of these units are from physics (again depending on concentration). The remainder are from other departments (chemistry, engineering, etc.), excluding math already accounted for above.</td>
<td>60 credits</td>
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<tr>
<td>Minimum # of upper-division</td>
<td>28 units</td>
<td>30-46 credits (major specific)</td>
<td>Total 31.3 to 48 equivalent semester units, depending on</td>
<td>45 credits</td>
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<tr>
<td>units required in the major</td>
<td>concentration, approx. 80% of these from physics</td>
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<tr>
<td>Minimum # of residency units to be completed in the major</td>
<td>30 units</td>
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<tr>
<td>30 of the last 45 units in residence at UW</td>
<td>23.3 equivalent semester units</td>
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<tr>
<td>30 credits</td>
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<tr>
<td>Required supporting coursework (courses that do not count towards major units and major GPA, but are required for the major). Courses listed must include subject code, units, and title.</td>
<td>MATH 122A/B or 125 (5/4) Calculus I</td>
<td></td>
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</tr>
<tr>
<td>-MATH 129 (3) Calculus II</td>
<td>-PHYS 229 Elementary Mathematical Physics (4)</td>
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<tr>
<td>-MATH 223 (4) Vector Calculus</td>
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<tr>
<td>-MATH 254 (3) Introduction to Ordinary Differential Equations</td>
<td>-PHYS 324 Introduction to nonrelativistic quantum mechanics (4)</td>
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<tr>
<td>Major requirements (list all required major coursework including major core, major electives, subplan core, subplan electives; courses count towards Introductory course requirements. PHYS 105A (1 unit), Introduction to Scientific Computing</td>
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<tr>
<td>PHYS 161H (4 units), Honors Introductory Mechanics</td>
<td>100-level Physics (15 cr)</td>
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<tr>
<td>-PHYS 121 (5) Mechanics</td>
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<td>-PHYS 122 (5) Electromagnetism</td>
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<tr>
<td>Preparatory Physics</td>
<td>MAT 265 (3) Calculus for Engineers I</td>
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<tr>
<td>MAT 266 (3) Calculus for Engineers II</td>
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<td>MAT 267 (3) Calculus for Engineers III</td>
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</table>
Courses listed must include course prefix, number, units, and title. Mark new coursework (New).

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<tr>
<th>100-level Math (15 cr)</th>
<th>Upper Division Requirements:</th>
<th>300-level Math Menu (3-4 cr)</th>
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<tbody>
<tr>
<td>PHYS 162H (4 units), Honors Introductory Optics and Thermodynamics</td>
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<tr>
<td>PHYS 261H (4 units), Honors Introductory Electricity and Magnetism</td>
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<td>PHYS 263H (3 units), Honors Introductory Relativity and Quantum Physics</td>
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<td>PHYS 204 (3 units), Mathematical Techniques in Physics</td>
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**100-level Math (15 cr)**

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<tr>
<td>MATH 124/134 (5) Differential Calculus</td>
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<td>MATH 125/135 (5) Integral Calculus</td>
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<tr>
<td>MATH 126/136 (5) Multivariable Calculus and Series</td>
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**200-level Physics (11 cr)**

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<tr>
<td>PHYS 224 (3) Thermal and Statistical Physics</td>
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<td>PHYS 225 (4) Mathematical Physics</td>
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<tr>
<td>PHYS 227 Quantum Mechanics I</td>
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<tr>
<td>PHYS 294 (1) Intro to Research: Frontiers of Physics</td>
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**300-level Math Menu (3-4 cr)**

<table>
<thead>
<tr>
<th>Course</th>
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<tr>
<td>MATH 307 or AMath 351 (3) Ordinary Differential Equations</td>
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**Upper Division Requirements:**

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<tr>
<td>PHYS 305 (3 units), Computational Physics</td>
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<td>PHYS 321 (3 units), Theoretical Mechanics</td>
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<tr>
<td>PHYS 331 (3 units), Electricity &amp; Magnetism I</td>
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<td>PHYS 371 (3 units), Quantum Theory</td>
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**300-level Math Menu (3-4 cr)**

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>MATH 307 or AMath 351 (3) Ordinary Differential Equations</td>
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**Depth Subject Matter (61-64 cr)**

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<tbody>
<tr>
<td>PHYS 104A (4) Introductory Methods of Mathematical Physics</td>
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<tr>
<td>PHYS 105A (4) Analytical Mechanics</td>
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<td>PHYS 110A (4) Electricity and Magnetism</td>
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**PHY 201 (3) Mathematical Methods in Physics I**

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<th>Course</th>
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<tr>
<td>PHYS 314 (3) Quantum Physics I</td>
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**PHY 361 (3) Introductory Modern Physics**

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<tr>
<td>PHYS 416 (3) Quantum Physics III</td>
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**PHY 460 (3) Numerical Methods in Modern Physics**

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<tr>
<td>PHYS 444 (3) Fundamentals of Nanoscience</td>
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<td>Course Title and Details</td>
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<tr>
<td>PHYS 381</td>
<td>(2 units), Methods in Experimental Physics I</td>
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<tr>
<td>PHYS 382</td>
<td>(2 units), Methods of Experimental Physics II</td>
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<td>Communication course (3 units):</td>
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<td>One course from the following: COMM/PR 119 (Public Speaking), ENGL 308 (Technical Writing), ENGL 340 (Topics in Professional and Technical Writing), JOUR 472 (Science Journalism), or JOUR 455 (Environmental Journalism).</td>
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<tr>
<td></td>
<td>Data analysis/statistics/modeling (3 units):</td>
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<td>One course from the following: ISTA 311 (Foundation of Information and Inference), ISTA 321 (Data Mining and Discovery), ISTA 350</td>
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<td>Data Acquisition and Analysis (7 cr):</td>
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<tr>
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<td>One course from the following:</td>
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<td></td>
<td>- PHYS 231 (3) Introductory Experimental Physics</td>
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<td></td>
<td>- AMath 301 (4) Beginning Scientific Computing (Matlab)</td>
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<td>Lab Requirement, Choose 1:</td>
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<tr>
<td></td>
<td>- PHY 116C (4) Introduction to Computer-Based Experiments in Physics</td>
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<td></td>
<td>300-level Physics (12 cr):</td>
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<td></td>
<td>- PHY 321 (4) Electricity and Magnetism I</td>
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<td>- PHY 322 (4) Electricity and Magnetism II</td>
</tr>
<tr>
<td></td>
<td>- PHY 334 (4) Electronics Laboratory</td>
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<td></td>
<td>- MATH 308 or AMath 352 (3) Linear Algebra</td>
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<td></td>
<td>- Math 309 or AMath 353 (3) Partial Differential Equations</td>
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<td>- MATH 324 (3) Vector Calculus</td>
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<td></td>
<td>- AMath 401 (4) Vector Calculus and Complex Variables</td>
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<td>- PHY 110B (4) Electricity and Magnetism</td>
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<td></td>
<td>- PHY 112 (4) Thermodynamics and Statistical Mechanics</td>
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<td>- PHY 115A (4) Foundation of Quantum Mechanics</td>
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<td>- PHY 116A (4) Electronic Instrumentation</td>
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<td></td>
<td>- PHY 116B (4) Electronic Instrumentation</td>
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<td></td>
<td>- PHY 102 (1) Computational Laboratory in Physics</td>
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<tr>
<td></td>
<td>- PHY 104B (4) Computational Methods of Mathematical Physics</td>
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<td>- PHY 499 (3) Individualized Instruction</td>
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<td>OR</td>
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<td>Upper Division Elective OR</td>
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<tr>
<td></td>
<td>PHY 484 (3) Internship</td>
</tr>
<tr>
<td></td>
<td>Upper Division Applied Physics Electives (Complete 9 Credit Hours). Choose from:</td>
</tr>
<tr>
<td></td>
<td>- MAT 343 (3) Applied Linear Algebra</td>
</tr>
<tr>
<td></td>
<td>- PHY 321 (3) Vector Mechanics and Vibration</td>
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<tr>
<td></td>
<td>- PHY 331 (3) Principles of Modern Electromagnetism</td>
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<td></td>
<td>- PHY 333 (3) Electronic Circuits and Measurements</td>
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<td>- PHY 361 (3) Introductory Modern Physics</td>
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<td></td>
<td>- PHY 456 (3) Laser Optics</td>
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<td></td>
<td>- PHY 495 (3) Project Research</td>
</tr>
<tr>
<td></td>
<td>- STP 420 (3) Introductory Applied Statistics</td>
</tr>
</tbody>
</table>
(Programming for Informatics Applications), ISTA 410 (Bayesian Modeling and Inference), ISTA 421 (Introduction to Machine Learning), or MATH 263 (Introduction to Statistics and Biostatistics).

**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.

**Core Physics (3-4 cr)**

ONE course selected from:
- PHYS 226 (3) Particles and Symmetries
- PHYS 323 (4) Electromagnetism III
- PHYS 324 (4) Quantum Mechanics II
- PHYS 328 (3) Statistical Mechanics
- PHYS 329 (3) Classical Mechanics

**Advanced Math (6-8 cr)**

TWO courses selected from:
- PHYS 229 (4) Mathematical Physics II
- MATH 307 (3) or AMath 351 (3) Ordinary Differential Equations

**Concentration Courses (20 cr)**

PHY 105C (4) Continuum Mechanics
ATM 120 (4) Atmospheric Thermodynamics and Cloud Physics
ATM 121A (4) Atmospheric Dynamics
ATM 121B (4) Atmospheric Dynamics
GEL 150A (4) Physical and Chemical Oceanography

**Additional electives, Choose 1:**

PHY 104B (4) Computational Methods of Mathematical Physics
**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. (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.)

| MATH 309 (3) or AMath 352 (3) Linear Algebra | PHY 116C (4) Introduction to Computer-Based Experiments in Physics |
| MATH 309 (3) or AMath 353 (3) Partial Differential Equations | GEL 116N (3) Oceanography |
| MATH 324 (3) Vector Calculus | ATM 128 (4) Radiation and Satellite Meteorology |
| AMath 401 (4) Vector Calculus and Complex Waves | MAT 118A (4) Partial Differential Equations: Elementary Methods |
| MATH 334, 335, 336 Honors Advanced Math | MAT 118B (4) Partial Differential Equations: Eigenfunction Expansions |

**Advanced Laboratory**

TWO lab courses selected from:

- PHYS 331 (3) Optics Lab
- PHYS 335 (3) Electronic Lab II
- CHEM 464 (3) or PHYS 434 (3) Computers in Data Acquisition and Analysis
- PHYS 431 (3) Modern Condensed Matter Physics Lab

For Applied Physics, concentrations exist in the following areas:

- Computational Physics
- Physical Electronics Concentration
- Geophysics
- Materials Science Concentration
- Physical Oceanography Concentration
- PHYS 432 (3) Modern Atomic Physics Lab
- PHYS 433 (3) Modern Nuclear and Particle Physics Lab
- ASTRO 480 (5) OR ASTRO 481 (5) Astronomical Data Analysis (480) or Acquisition (481)

**Electives (9cr)**

**Capstone (3cr)**
3 units from list:
- PHYS 494
- PHYS 495
- PHYS 496
- PHYS 499
- ASTR 481
- PHYS 499

Depending on the concentration, students can be required to take a wider variety of preparatory subject matter and different courses for their Depth Coursework.

<p>| Internship, practicum, | No | No | No | Optional (choose upper division elective or an |</p>
<table>
<thead>
<tr>
<th>applied course requirements (yes/no). If yes, provide description.</th>
<th></th>
<th></th>
<th>internship, research is an optional elective as well) Students can enroll in PHY 495: Project Research as one of their electives or take PHY 484: Internship in place of an elective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior thesis or senior project required (yes/no)</td>
<td>Yes, ENGR 498A and B (or equivalent internship in multidisciplinary teams). Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Capstone (3cr) 3 units from list: PHYS 494 PHYS 495 PHYS 496 PHYS 499 ASTR 481 PHYS 499</td>
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<tr>
<td>Additional requirements</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<tr>
<td>Minor required?</td>
<td>Optional</td>
<td>Optional</td>
<td>Optional</td>
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</tbody>
</table>
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, 492 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 engineering design project (6 units). All other requirements are the same.
# BS Applied Physics

Courses and Activities Mapped to BS Applied Physics Outcome Set

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Intro Physics</th>
<th>Experiment Design</th>
<th>Communication</th>
<th>Mathematical/Computation Skills</th>
<th>Multidisciplinarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Physics Knowledge</td>
<td>PHYS 105</td>
<td>PHYS 161H</td>
<td>PHYS 305</td>
<td>PHYS 163H</td>
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</tr>
<tr>
<td>Core knowledge that form the basis of classical mechanics, quantum mechanics, electromagnetism, optics and thermodynamics</td>
<td>Introduction to Scientific Computing</td>
<td>Introduction to Mechanics;</td>
<td>Computational Physics;</td>
<td>Introduction to Modern Physics</td>
<td>Ability to work in multidisciplinary teams to address technological problems arising in academic, government or private sectors</td>
</tr>
<tr>
<td>Design, conduct, and analyze experiments to optimize engineering Research &amp; Development and to investigate underlying physical phenomena.</td>
<td>PHYS 162H Introduction to Thermodynamics;</td>
<td>PHYS 261H Introduction to Electricity and Magnetism;</td>
<td>Ability to communicate experimental results and to present engineering design solutions in written and oral form.</td>
<td>Proficiency in using mathematical or computational skills to investigate physical phenomena or to optimize solutions to technological problems</td>
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<td></td>
<td>PHYS 263H Introduction to Modern Physics</td>
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</tbody>
</table>

## Courses and Learning Activities

### Intro Physics

**Introductory Physics Courses**

- PHYS 105 Introduction to Scientific Computing
- PHYS 161H Introduction to Mechanics
- PHYS 162H Introduction to Thermodynamics
- PHYS 261H Introduction to Electricity and Magnetism
- PHYS 263H Introduction to Modern Physics

<table>
<thead>
<tr>
<th>Intro Physics</th>
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### Physics Core

**Advanced Physics Courses**

- PHYS 305 Computational Physics;

<table>
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<tr>
<th>Physics Core</th>
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<td>Outcome</td>
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<tr>
<td>Core Physics Knowledge</td>
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<tr>
<td>Core knowledge that form the basis of classical mechanics, quantum mechanics, electromagnetism, optics and thermodynamics</td>
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<tr>
<td><strong>PHYS 321 Theoretical Mechanics I; PHYS 331 Electricity &amp; Magnetism; PHYS 371 Quantum Mechanics I; PHYS 381 Methods in Experimental Physics I; PHYS 382 Methods in Experimental Physics II</strong></td>
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<tr>
<td>Communication</td>
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<tr>
<td>Science/Physics Communication</td>
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<tr>
<td><strong>COMM 119 Public Speaking; ENGL 308; Scientific and technical communication; ENGL 340 Topics in professional and technical writing; JOUR 472 Science journalism; JOUR 455 Environmental journalism.</strong></td>
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<td>Data Science</td>
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<tr>
<td>Data Analysis, Statistics, Modeling</td>
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<tr>
<td><strong>ISTA 311 Foundation of information and inference; ISTA 350 Programming for informatics; ISTA 421 Introduction to machine learning; MATH 263 Introduction to statistics and biostatistics</strong></td>
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<td>Capstone</td>
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<td>Multidisciplinarity</td>
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<tr>
<td>Ability to work in multidisciplinary teams to address technological problems arising in academic, government or private sectors</td>
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<tr>
<td>Outcome</td>
<td>Core Physics Knowledge</td>
<td>Experiment Design</td>
<td>Communication</td>
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<td>Multidisciplinarity</td>
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<tr>
<td>Core knowledge that form the basis of classical mechanics, quantum mechanics, electromagnetism, optics and thermodynamics</td>
<td>Design, conduct, and analyze experiments to optimize engineering Research &amp; Development and to investigate underlying physical phenomena.</td>
<td>Ability to communicate experimental results and to present engineering design solutions in written and oral form.</td>
<td>Proficiency in using mathematical or computational skills to investigate physical phenomena or to optimize solutions to technological problems</td>
<td>Ability to work in multidisciplinary teams to address technological problems arising in academic, government or private sectors</td>
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</table>

**Capstone Design Project**  
Engr 498A and Engr 498B Senior engineering design project

**Legend:**
- **I** Introduced
- **P** Practiced
- **A** Assessed

**Last Modified:** 12/08/2018 10:23:11 AM
## Budget Projection Form

**Name of Proposed Program or Unit:** APPLIED PHYSICS (HIGH PROJECTION)

### Metrics

<table>
<thead>
<tr>
<th></th>
<th>1st Year 2019 - 2020</th>
<th>2nd Year 2020 - 2021</th>
<th>3rd Year 2021 - 2022</th>
<th>4th Year 2022 - 2023</th>
<th>5th Year 2023 - 2024</th>
<th>6th Year 2024 - 2025</th>
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</thead>
<tbody>
<tr>
<td>Net increase in annual college enrollment UG</td>
<td>30</td>
<td>40</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>Net increase in total college enrollment UG (all four years)</td>
<td>30</td>
<td>66</td>
<td>102</td>
<td>134</td>
<td>150</td>
<td>158</td>
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<tr>
<td>Net increase in college SCH UG</td>
<td>250</td>
<td>617</td>
<td>1,055</td>
<td>1,460</td>
<td>1,669</td>
<td>1,733</td>
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<tr>
<td>Net increase in annual college enrollment Grad</td>
<td></td>
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<tr>
<td>Net increase in college SCH Grad</td>
<td></td>
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<tr>
<td>Number of enrollments being charged a Program Fee</td>
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<tr>
<td>New Sponsored Activity (MTDC)</td>
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<td>Number of Faculty FTE</td>
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</table>

### Funding Sources

**Continuing Sources**
- UG RCM Revenue (net of cost allocation) $80,045
- Grad RCM Revenue (net of cost allocation) $190,090
- Program Fee RCM Revenue (net of cost allocation) $314,960
- F and A Revenues (net of cost allocations) $429,228
- UA Online Revenues $487,719

**One-time Sources**
- College fund balances $- $-
- Institutional Strategic Investment $- $-
- Gift Funding $- $-

**Total Continining** $80,045 $190,090 $314,960 $429,228 $487,719 $508,507

**Total One-time** $- $- $- $- $- $-

**Total Sources** $80,045 $190,090 $314,960 $429,228 $487,719 $508,507

### Expenditure Items

**Continuing Expenditures**
- Faculty/Lecturer $55,000 $55,000 $135,000 $135,000
- Other personnel - Academic Advisor $21,500 $21,500 $21,500 $21,500
- Student Employee $5,200 $5,200 $5,200 $5,200
- Employee Related Expense $12,170 $34,688 $37,367 $62,327 $62,327
- Graduate Assistantships $38,000 $76,000 $95,000 $95,000
- Other Graduate Aid (tuition remission) $23,432 $48,756 $62,165 $63,410 $64,675
- Operations (materials, supplies, phones, etc.) $23,432 $48,756 $62,165 $63,410 $64,675
- Additional Space Cost $- $-
- Other Items (attach description) $- $-

**Total Continuing** $100,302 $134,399 $241,144 $276,232 $382,437 $383,702

**One-time Expenditures**
- Construction or Renovation $- $-
- Start-up Equipment $- $-
- Replace Equipment $- $-
- Library Resources $- $-
- Other Items (attach description) $- $-

**Total One-time** $- $- $- $- $- $-

**Total Expenditures** $100,302 $134,399 $241,144 $276,232 $382,437 $383,702

**Net Projected Fiscal Effect** $- $55,691 $73,816 $152,996 $105,282 $124,805
### METRICS

<table>
<thead>
<tr>
<th></th>
<th>1st Year 2019-2020</th>
<th>2nd Year 2020-2021</th>
<th>3rd Year 2021-2022</th>
<th>4th Year 2022-2023</th>
<th>5th Year 2023-2024</th>
<th>6th Year 2024-2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net increase in annual college enrollment UG</td>
<td>12</td>
<td>25</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Net increase in total college enrollment UG (all four years)</td>
<td>12</td>
<td>36</td>
<td>68</td>
<td>93</td>
<td>109</td>
<td>116</td>
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<tr>
<td>Net increase in college SCH UG</td>
<td>74</td>
<td>310</td>
<td>670</td>
<td>981</td>
<td>1,157</td>
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<tr>
<td>Net increase in annual college enrollment Grad</td>
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<tr>
<td>Net increase in college SCH Grad</td>
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</tr>
</tbody>
</table>

### FUNDING SOURCES

**Continuing Sources**
- UG RCM Revenue (net of cost allocation) | 26,589 | 98,142 | 203,013 | 291,156 | 342,756 | 356,561 |
- Grad RCM Revenue (net of cost allocation) |                |                |            |            |            |            |
- Program Fee RCM Revenue (net of cost allocation) |            |            |            |            |            |            |
- F and A Revenues (net of cost allocations) |            |            |            |            |            |            |
- UA Online Revenues |            |            |            |            |            |            |
- Distance Learning Revenues |            |            |            |            |            |            |
- Reallocation from existing College funds (attach description) |            |            |            |            |            |            |
- Other items (attach description) |            |            |            |            |            |            |
- **Total Continuing** | **$26,589** | **$98,142** | **$203,013** | **$291,156** | **$342,756** | **$356,561** |

**One-time Sources**
- College fund balances |                |                |            |            |            |            |
- Institutional Strategic Investment |                |                |            |            |            |            |
- Gift Funding |                |                |            |            |            |            |
- Other items (attach description) |                |                |            |            |            |            |
- **Total One-time** | **$** | **$** | **$** | **$** | **$** | **$** |
- **TOTAL SOURCES** | **$26,589** | **$98,142** | **$203,013** | **$291,156** | **$342,756** | **$356,561** |

### EXPENDITURE ITEMS

**Continuing Expenditures**
- Faculty/Lecturer |                |                |            |            |            |            |
- Other personnel - Academic Advisor |                |                |            |            |            |            |
- Student Employee | 5,200 | 5,200 | 5,200 | 5,200 | 5,200 | 5,200 |
- Employee Related Expense | 2,783 | 5,462 | 14,849 | 34,688 | 34,688 | 59,648 |
- Graduate Assistantships | 19,000 | 38,000 | 57,000 | 76,000 | 76,000 | 76,000 |
- Other Graduate Aid (tuition remission) | 11,716 | 23,900 | 36,567 | 49,732 | 50,728 | 51,740 |
- Operations (materials, supplies, phones, etc.) |                |                |            |            |            |            |
- Additional Space Cost |                |                |            |            |            |            |
- Other items (attach description) |                |                |            |            |            |            |
- **Total Continuing** | **$38,699** | **$72,562** | **$135,116** | **$242,120** | **$243,116** | **$349,088** |

**One-time Expenditures**
- Construction or Renovation |                |                |            |            |            |            |
- Start-up Equipment |                |                |            |            |            |            |
- Replace Equipment |                |                |            |            |            |            |
- Library Resources |                |                |            |            |            |            |
- Other items (attach description) |                |                |            |            |            |            |
- **Total One-time** | **$** | **$** | **$** | **$** | **$** | **$** |
- **TOTAL EXPENDITURES** | **$38,699** | **$72,562** | **$135,116** | **$242,120** | **$243,116** | **$349,088** |

**Net Projected Fiscal Effect** | **$(12,110)** | **$25,580** | **$67,897** | **$49,036** | **$99,640** | **$7,473** |
MEMO

DATE: 12/7/18

TO: Pamela Coonan, Executive Director
    Academic & Curricular Affairs

FROM: Sumitendra Mazumdar, Department Head
      Department of Physics

RE: Disestablishment of Physics BA Program

The Department of Physics requests the disestablishment of the Bachelor of Arts degree in Physics. The last admit term for the program should be Fall 2018. The degree is currently unproductive, graduating roughly one student per year. Our intent is to replace it with the proposed BS in Applied Physics, which better prepares students for nonacademic careers in the private sector.

All current BA Physics students can continue to take coursework toward the completion of their BA degree, since all of the required and elective physics courses will continue to be taught for BS students. However, our intent is to stop accepting new BA students and instead (from Fall 2019 onwards) steer them toward a BS in Applied Physics.

If there is any information you need in order to move forward with this request, please let us know.
BIOGRAPHICAL SKETCH

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.,
3. “Spectroscopic needs for imaging dark energy experiments,” J. A. Newman et al.,
4. “Precise Measurements of Direct CP Violation, CPT Symmetry, and Other Parameters in
5. “Development of large size Micromegas detector for the upgrade of the ATLAS muon
7. “Cathode strip chambers in ATLAS: Installation, commissioning and in situ
8. “Final Results from the KTeV Experiment on the Decay $K_L \rightarrow \pi^0\gamma\gamma$, ” E. Abouzaid et al.,
9. “A Combined search for the standard model Higgs boson at $\sqrt{s} = 1.96$-TeV,” V.M. Abazov et al.,
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,  

“De Broglie wave-front curvature induced by electric-field gradients and its effect on precision measurements with an atom interferometer,”  

“Measurement of a Wavelength of Light for Which the Energy Shift for an Atom Vanishes,”  

“Can atom–surface potential measurements test atomic structure models?,”  
V.P. A. Lonij, C.E. Klauss, W.F. Holmgren, and A.D. Cronin,  

“Atom diffraction reveals the impact of core electrons on atom-surface potentials,”  
V.P.A. Lonij, W. Holmgren, C. Klauss, A.D. Cronin,  

Five additional publications:

“Atom Interferometer Gyroscope with Spin-Dependent Phase Shifts Induced by Light near a Tune-Out Wavelength,”  

“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,  

“Observation of atom wave phase shifts induced by van der Waals atom-surface interactions,”  
J.D. Perreault, T.A. Savas, A.D. Cronin,  

“From single- to multiple-photon decoherence in an atom interferometer,”  
D.A. Kokorowski, A.D. Cronin, T.D. Roberts, and D.E. Pritchard,  

“Optics and interferometry with atoms and molecules,”  
A.D. Cronin, J. Schmiedmayer, D.E. Pritchard,  

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


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

<table>
<thead>
<tr>
<th>Institution</th>
<th>Position</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSF</td>
<td>Program Director, HEP Theory</td>
<td>current</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>Full Professor</td>
<td>8/09 – current</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>Director of Graduate Studies, Physics</td>
<td>8/05 – 7/09</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>Associate Professor</td>
<td>8/03 – 8/09</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>Assistant Professor</td>
<td>8/99 – 8/03</td>
</tr>
<tr>
<td>CERN Theory Division</td>
<td>Postdoctoral Fellow</td>
<td>9/97 – 8/99</td>
</tr>
<tr>
<td>IAS, Princeton</td>
<td>Postdoctoral Fellow</td>
<td>8/94 – 8/97</td>
</tr>
<tr>
<td>McGill University</td>
<td>Postdoctoral Fellow</td>
<td>8/91 – 8/94</td>
</tr>
<tr>
<td>Cornell University</td>
<td>Graduate Research Asst.</td>
<td>8/87 – 8/91</td>
</tr>
</tbody>
</table>

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, 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:  
   Grand Unification at Intermediate Mass Scales through Extra Dimensions, Nucl. Phys. B537, 47 (1999);  
   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.


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
  - “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**  
**Ph.D.:** Physics.

**GEORGETOWN UNIVERSITY**  
**B.Sc.:** Physics

**Employers**

**UNIVERSITY OF ARIZONA**  
**Professor,** 2016–Date.  
**Associate Professor,** 2011 – 2016.  
**Assistant Professor,** 2005–2011

**UNIVERSITY OF CALIFORNIA SAN DIEGO**  

**CARNEGIE MELLON UNIVERSITY**  

**UNIVERSITY OF TORONTO**  

**UNIVERSITY OF WISCONSIN**  

**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.
3. Ou Zhang, Joined group Fall 2011, Research Topic: Effective Field Theories of Strong Interactions (Graduated December 2016).
## Supervised


## 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.
8. **Faculty & Staff Awards:** 2013–2014.
9. **Student & Staff Awards:** 2010–2012.
11. **Grad Advisor:** 2007–Date.

## 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.
7. **Graduate Quantum Mechanics:** Fall & Spring 2006 – Spring 2009.

## Recent Articles

Samuel E. Gralla

Assistant Professor of Physics  
Core faculty, Theoretical Astrophysics Program  
The University of Arizona

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
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


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 DØ experiment, 2002 - 2007
3. Head of the L1 Muon Trigger Project for the DØ experiment, 1995 - 2007
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)

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
  University of Arizona Physics Department
  (8/2017-present)

• Postdoctoral Scholar
  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
  (9/2013-8/2017)

• Postdoctoral Scholar
  Max-Planck institute of Quantum Optics (MPQ), Munich, Germany
  Faculty Mentor: Prof. Dr. Ferenc Krausz and Dr. Eleftherios Goulielmakis
  (2/2013-9/2013)

Education

• Ph.D. in Physics
  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”.
  (7/2009-3/2013)

• M.Sc. and Diploma in Laser Interactions with Matter (ranking #1)
  National Institute of Laser Enhanced Science, Cairo University, Egypt.
  Thesis Topic: “Cancer treatment with naturally synthesized gold nanoparticles”.
  (9/2004-6/2009)

• B.Sc. in Chemistry (ranking top 5%) 
  Faculty of Science, Cairo University, Egypt.
  (9/1999-9/2013)

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.
• 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)

Refereed Publications


   *corresponding author contribution

   **News and Views**
   
   Attosecond photonics: Imaging ultrafast electron dynamics (*Nature Photonics*).


   **News and Views**
   
   Laser-driven nanoparticle motion in liquids (*Science*).


   **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*)

   **News and Views**
   
   Sluggish electrons caught in action (*ChemEurop*).


Invited Talks

1. Attomicroscopy: Towards imaging the electron motion in real-time, UFO XI, October 2017, WY, USA.


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.
6. Electron Motion Control and Imaging, Physics Department at the University of Southern California (USC), March 2016, Los Angeles, CA, USA.
7. Attosecond bound electron control, The Research Laboratory of Electronics (RLE) at the Massachusetts Institute of Technology (MIT), Jul 2015, Cambridge, MA, USA.
9. Attosecond electron control, Physics Department, Caltech, Oct 2014, Pasadena, California, USA.
10. Attosecond light field synthesis, Attosecond Workshop, July 2012, Munich, Germany.
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 Prefecture University (Okayama, Japan), 1998-2000;
Associate Professor: Tohoku University (Sendai, Japan), 1995-1997;
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

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);
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);
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).

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

2. “Pressure-induced commensurate stacking of graphene on boron nitride”

3. “van der Waals heterostructures with high accuracy rotational alignment”

4. “Local spectroscopic characterization of spin and layer polarization in WSe2”

5. “Intrinsic disorder in graphene on transition metal dichalcogenide heterostructures”

Five other significant publications
6. “Electric field control of soliton motion and stacking in trilayer graphene”
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,

8. “Emergence of superlattice Dirac points in graphene on hexagonal boron nitride”
M. Yankowitz, J. Xue, D. Cormode, J. Sanchez-Yamagishi, K. Watanabe, T.
(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.
(2011).

10. “Spatially resolved spectroscopy of monolayer graphene on SiO2”
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

A.E. Murdaugh, M. Liddelow, A.M. Schmidt* and S. Manne, “Two-Dimensional Crystal Growth From

M.B. Hay*, R.K. Workman and S. Manne, “Two-Dimensional Condensed Phases from Particles with


FIVE OTHER SIGNIFICANT PUBLICATIONS


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

Advisors

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

Former Graduate Students (5)

BIOGRAPHICAL SKETCH
Sumitendra Mazumdar

Education and Training:
Ph.D. (Chemistry), Princeton University (1980).

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:
Synergistic Activities:


Collaborators during the past 48 months:

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:

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 $\rho$ 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].


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].


8. R. R. Horgan, Z. Liu, S. Meinel, M. Wingate, “Calculation of $B^0 \to K^{*0}\mu^+\mu^-$ and $B^0_s \to \phi\mu^+\mu^-$ observables using form factors from lattice QCD,” Phys. Rev. Lett. 112, 212003 (2014) [arXiv:1310.3887].


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

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.
Professorial Fellow, School of Physics, Melbourne University, Australia 2005 - present.
Year's Best Astronomy Book worldwide, The Edge of Infinity, Astronomy 2005 Special Issue.
Fellow of the American Physical Society, 2002 - present.
Sir Thomas Lyle Fellow (Australia) for Distinguished International Visitors, 1998 - 1999.
Presidential Young Investigator Award (Physics), 1988 - 1994.

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 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.
Member of ERC, 2015-present.

Previous Appointments
Simpson Chair, Amherst College, 2010-2012.
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)


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.
Affiliate, Theoretical Astrophysics at The University of Arizona

http://www.physics.arizona.edu/~rafelski/vitaeP.html
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  Physics Division, Argonne National Laboratory, Chicago
        from 1975 Junior Staff
        from 1977 on leave
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  Munich Center for Advanced Photonics, LMU
1992  Guest Scientist  MPI Max Planck Institut für Physik Munich
1993-06 Guest Professor  Université 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

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 separate. 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).
**List of Refereed Publications**

*(narrow definition: research reports submitted to journal of own choice subject to blind refereeing; this excludes numerous i) invited research reports; and ii) refereed conference reports)*


16. **Properties of Gravitationally Bound Dark Compact Ultra Dense Objects.**


54. Strange hadrons and their resonances: A Diagnostic tool of QGP freezeout


158. Bose Condensation in Supercritical External Fields. 2. Charged


180. Solution of the Dirac equation with two Coulomb centers. B. Muller, J.


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**Conference Reports** (including invited and refereed contributions)


Nov 2013. Budapest, Hungary


Max Born Symposium and HIC for FAIR Workshop **Three Days of critical behavior in hot and dense QCD** 14-16 Jun 2013. Wroclaw, Poland


34. **Strangeness enhancement at LHC**. J. Rafelski, J. Letessier.
35. Particle Production and Deconfinement Threshold. J. Rafelski, J. Letessier.
   PoS CONFINEMENT8 (2008) 111
   Quark Confinement and the Hadron Spectrum (Confinement VIII) 1-6 Sep 2008.
   Mainz, Germany

36. (Contributions in group special issue) Heavy Ion Collisions at the LHC-Last Call for Predictions. N. Armesto et al..

   Memorial Workshop on Hadronic and Quark Matter 2-4 Jul 2007.
   Budapest, Hungary

   ISHIP 2006 3-6 Apr 2006.
   Frankfurt, Germany

   XLVI Cracow School of Theoretical Physics, May 25-June 5, 2006
   Zakopane, Poland

40. Strangeness and thresholds of phase changes in relativistic heavy ion collisions. J. Rafelski, J. Letessier.
    Cairns, Queensland, Australia

41. (Contribution to experimental collaboration special issue) ALICE: Physics performance report, volume II.

    Budapest, Hungary

    Budapest, Hungary

    Budapest, Hungary

    Salt Lake City, Kolkata, India

46. Hadronization and quark probes of deconfinement at RHIC. H.Z. Huang, J. Rafelski.
    Villasimius, Sardinia, Italy

    XLIV Cracow School of Theoretical Physics, May 28-June 6, 2004.
    Zakopane, Poland

48. Multiplicities and bulk thermodynamic quantities at s(NN)**(1/2) =


88. **Renormalization group and thermal flavor production in OGP**, J. Rafelski, J.


1991. Geneva, Switzerland


120. (Special publication by US Department of Commerce NBS [now NIST]) Perspectives in High Energy Nuclear Collisions. J. Rafelski, M. Danos. Downloaded from National Technical Information Service (NTIS); Accession Number PB83-223982 print NBSIR-83-2725 (Washington D.C. 1983); also available Preprint GSI-83-6


Formation and Observables of the Quark-Gluon Plasma

J. Rafelski. Full Conference Proceedings - see pp 625-648 for this contribution Heavy Ion Session Rencontres De Moriond: Elementary Hadronic Processes and Heavy Ion Interactions March 14-26, 1982, Les Arcs, France


Heavy Quark-Anti-quark Bound States in the Framework of Quantum

Contributed to: International conference on high energy physics and nuclear structure, 13-17 Aug 1979 Vancouver, Canada


Problems of high-field electrodynamics in heavy-ion scattering. (talk, in german). J. Rafelski. p 94-110 in Darmstadt Schwerionenforsch GSI 72-10 (1972),

Unpublished research reports (Includes statutory (funding, thesis) reports, works prepared with intend to publish but authors could not agree to common response to the referee, and works with main theme absorbed into another later project)

7. **Pair Production from Asymmetric Head-on Laser Collisions.** L. Labun, J. Rafelski. [arXiv:1107.6026 [hep-ph]].
10. **Deconfinement energy threshold: Analysis of hadron yields at 11.6-A GeV.** J. Letessier, J. Rafelski, G. Torrieri. [nucl-th/0411047]
12. **Variation of fine structure constant from nonuniversal gravity.** J. Rafelski. [hep-ph/0208259].
13. **Macroconstraints from microsymmetries of macrosystems.** L. Turko, J. Rafelski. [nucl-th/011047].
19. **Spontaneous Production of Light Neutral Particles In Heavy Ion Collisions.** B. Muller, J. Rafelski. UFTP-177-1986, UCT-TP-68 Sep 1986.
27. **Selbstkonsistente Vielteilchengleichungen fur Elektronen und Muonen.**
Books and chapters in books


Danos, J. Rafelski. pp. 332-341


General Interest; Popular Science
   3. The tale of the Hagedorn temperature, J. Rafelski, T. Ericson. CERN Cour.
43 N7 (2003) 30-33..

page updated August 25, 2017; added publications September 3, 2017 Return to home page
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
Advisor: Matthew Deady.

Honors, Awards, and Fellowships: Research
2018 Cottrell Scholar Award.
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 Berta and Harold J. Drescher Scholarship, Bard College.
1996 Colombian representative to the XXVII International Physics Olympiad, Oslo, Norway.

Honors, Awards, and Fellowships: Teaching
2018 Cottrell Scholar Award

Leadership Positions
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 ($100,000).
- 2018–2020 coI, Chandra Calibration of the Richness-Mass Relation of Galaxy Clusters. ($\approx 34,000$).
- 2017–2018 PI, Faculty Seed Grant ($\approx 10,000$).
- 2016–2020 PI, DOE Early Career Award ($\approx 750,000$).
- 2016–2017 PI, Sloan Fellowship in Physics ($500,000$).
- 2015–2016 PI, Chandra Calibration of the Richness–Mass Relation of Galaxy Clusters. ($\approx 38,000$)
- 2009–2012 PI, Einstein Fellowship, NASA grant PF9-00068, ($\approx 350,000$).

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.
- Meetings organized: Convener for CPAD Meeting 2015, SOC 2014 Planck Ferrara Conference, SOC-chair for the 2014 DES collaboration meeting, 10th Great Lakes Cosmology Workshop (GLCW), 8th GLCW, DES Cluster Comparison workshop.

Educational and Community Outreach Activities:

- 2015–present Cofounded TIMESTEP, the Tucson Initiative for Minority Engagement in STEM Program.
- 2015–present Faculty Mentor for the Women in Physics (WiP) student group at Arizona.
- 2015–present Volunteer Faculty mentor for UROC SRI, LASRP.
- 2016 Volunteer Presenter for the Tucson Association of Physics Teachers.

1TIMESTEP 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.

2WiP was recently awarded the Excellence in STEM Diversity Award by the Women in Science and Engineering (WISE) program at the University of Arizona.

3UROC 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.

4LASRP 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 Snowchuster, Salt Lake City, Utah.
Mentoring Experience: minority or female students are noted by a †.

Current Graduate Students:
Christopher Davies
Tom McClintock
†Erika Lynn Wagoner
Matthew Kirby
Pier Fiedorowicz
†Rafael García

Current Graduate Students:
Christopher Davies Stanford University
Tom McClintock University of Arizona
†Erika Lynn Wagoner University of Arizona
Matthew Kirby University of Arizona
Pier Fiedorowicz University of Arizona
†Rafael García University of Arizona

Past Graduate Students:
Fabian Schmidt
†Hao-Yi Wu
Christopher Greer
Matthew Becker
Eric Jones Baxter

Past Graduate Students:
Fabian Schmidt U. of Chicago (faculty at Max Planck Institute for Astronomy)
†Hao-Yi Wu Stanford University (postdoc at The Ohio State University)
Christopher Greer University of Chicago (postdoc at University of Arizona)
Matthew Becker University of Chicago (Data Scientist at Civis Analytics)
Eric Jones Baxter University of Chicago (postdoc at the U. of Pennsylvania)

Current Undergraduate Students:
Matthew Mitchell
†Sasha Safonova

Current Undergraduate Students:
Matthew Mitchell University of Arizona
†Sasha Safonova University of Arizona

Past Undergraduate Students:
†Ellie Kitanidis

Past Undergraduate Students:
†Ellie Kitanidis Stanford University (grad student at UC Berkeley)
Pier Fiedorowicz
†Kaitlin McElroy

Past Undergraduate Students:
Pier Fiedorowicz University of Arizona (grad. student at Arizona)
†Kaitlin McElroy University of Arizona (graduated 2017)

Current or Past Summer Students:
†Cristian Baldenegro
†Ian Avilez
†Rafael García
†Edgar Marrufo
†Edgar Salazar
†Allania Lopez

Current or Past Summer Students:
†Cristian Baldenegro Universidad de Sonora, Mexico
†Ian Avilez Northern Arizona University
†Rafael García Universidad de Sonora, Mexico
†Edgar Marrufo Northern Arizona University
†Edgar Salazar Universidad de Sonora, Mexico
†Allania Lopez Universidad de Sonora, Mexico
References

Scott Dodelson
Scientist III
Fermi National Accelerator Laboratory
Box 500 MS-209 ◊ Batavia, IL 60510 ◊ USA
Tel: (630) 840-2426 ◊ E-mail: dodelson@fnal.gov

Bhuvnesh Jain
Walter H. and Leonore C. Annenberg Professor in the Natural Sciences
Co-Director of the Penn Center for Particle Cosmology
Department of Physics and Astronomy, University of Pennsylvania
209 South 33rd Street, Philadelphia, PA 19104-6396
Tel: (215) 573-5330 ◊ E-mail: bjain@physics.upenn.edu

Risa Wechsler
Associate Professor
Department of Physics, Stanford University
382 Via Pueblo Road ◊ Stanford University, Stanford, CA 94305 ◊ USA
Tel: (650) 926-3621 ◊ E-mail: rwechsler@stanford.edu

David Weinberg
University Distinguished Scholar ◊ Distinguished Professor of Mathematical & Physical Sciences
Department of Astronomy, The Ohio State University
McPherson Laboratory ◊ 140 W. 18th Ave. ◊ Columbus, OH 43210, USA
Tel: (614) 292-6543 ◊ E-mail: dhw@astronomy.ohio-state.edu

John Carlstrom
Subramanyan Chandrasekhar Distinguished Service Professor
Departments of Astronomy and Astrophysics and Department of Physics, University of Chicago
5640 S. Ellis Ave. ◊ Chicago, IL 60637 ◊ USA
Tel: (773) 834-0269 ◊ E-mail: jc@kicp.uchicago.edu

August Evrard
Arthur F. Thurnau Professor of Physics and Astronomy
Department of Physics, University of Michigan
450 Church St. ◊ Ann Arbor, MI 48109-1040 ◊ USA
Tel: (734) 764-4366 ◊ E-mail: evrard@umich.edu

Andrey Kravtsov
Associate Professor
Department of Astronomy & Astrophysics, University of Chicago
5640 S. Ellis Ave. ◊ Chicago, IL 60637 ◊ USA
Tel: (773) 702-4249 ◊ E-mail: andrey@oddjob.uchicago.edu
Publications

Citation statistics taken from ADS Citation Metrics.

Reviews/White Papers:


Refereed Publications: As a member of several large collaborations, there are several papers in which I am included as one of \( \approx 10 \) – 100 authors despite having contributed little effort. These papers are not included in the list below. Papers marked with three asterisks (*** ) included research carried out while in graduate school. All other papers were written while working as an independent researcher.


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


Leadership positions

Spokesperson: Large Angle Compton Scattering (TUMM), Cornell 1975 – 1976
Deputy Spokesperson: High-Mass Dimuons (E439), Fermilab 1976-1979
Fermilab Program Advisory Committee 1986 - 1991
APS/DPF Executive Committee 1995 - 1997
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


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.


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.

Selected Publications


Synergistic activities
- Chair, Attosecond Transient Absorption Session, DAMOP 2014, Madison, WI (2014).

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 (Louisiana State University)
- Prof. Mette Garde (Louisiana 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
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.
Ten Selected Publications


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


**Five other significant publications**


**Synergistic Activities:**


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


**Patents** (relevant to this project)


**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.


3. Supervised the research (for academic credit) of eight undergraduate students in the past three years, including three members of under-represented groups.


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**

- 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
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


Chronology of Education

1995-2000 Massachusetts Institute of Technology
Ph.D. in Physics, June, 2000.
Thesis Advisor: Prof. Lisa Randall

1990-1995 University of Science and Technology of China
B.S. in Physics, June, 1995.
Thesis Advisor: Prof. Yunxiu Ye
Thesis: A 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

- 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

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
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:


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. Buen-dia (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
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
- 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
- \textit{in}SPIRE: 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, \(i_{10}=84, h=48\)

Five Major Publications (Citations in \textit{in}SPIRE):

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.


2. “Search for the standard model Higgs boson in the $ZH \rightarrow \nu\nu bb$ 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)


Curriculum Vitae  Koen Visscher

CHRONOLOGY OF EDUCATION

University of Amsterdam, The Netherlands, Ph.D., May 27 1993, Physics
  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.


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,

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

HONORS AND AWARDS
• Proceeding of the Royal Society A, top reviewer, 2011
• Joop Los Fellow, FOM Institute for Atomic and Molecular Physics (AMOLF, sabbatical), Amsterdam, 2007.
• Arnold and Mabel Beckman Foundation, Beckman Young Investigator Award, 2001.
• Research Corporation, Research Innovation Award, 2000.

SELECTED PUBLICATIONS
Visscher, K. Programmed Ribosomal Frameshifting as a force-dependent process, in Progress in Molecular Biology and Translational Science 139, 45-72 (2016)
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).
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
  Department of Physics, University of Arizona
  Aug 2012-present

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


Five Other Significant Publications

Synergistic Activities

- **Program Committee Member:**
  - 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
- **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

<table>
<thead>
<tr>
<th>Institution</th>
<th>Field</th>
<th>Degree</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Arizona, AZ</td>
<td>Physics</td>
<td>B.Sc.</td>
<td>1995</td>
</tr>
<tr>
<td>University of Arizona, AZ</td>
<td>Physics</td>
<td>M.S.</td>
<td>1996</td>
</tr>
<tr>
<td>University of Arizona, AZ</td>
<td>Physics</td>
<td>Ph.D.</td>
<td>2000</td>
</tr>
<tr>
<td>University of California, Berkley, CA</td>
<td>Molecular and Cellular Biology</td>
<td></td>
<td>2000-2002</td>
</tr>
</tbody>
</table>

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.

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.

Associate Professor of Cell Biology (with adjunct appointments in Physics and Biomedical Engineering), University of Connecticut Health Center

Assistant Professor of Cell Biology, University of Connecticut Health Center

1.3 Publications

1.3.1 Publications Most Closely Related to This Proposal


1.3.2 Other Significant Publications


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
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


**Five other publications**


A complete list of publications can be found at https://scholar.google.com, search for Shufeng Zhang.
Undergrad survey: New major in Applied Physics

Brief description: The Physics Department is proposing to offer a new major in Applied Physics, alongside the traditional major in (Comprehensive) Physics. The new major will be geared toward students who do NOT intend to become professional physicists after their BS degree. Roughly half of our graduating seniors follow a “traditional” physics track (grad school in physics/astronomy, then research positions in academia, national labs or industry). The other half go directly into the private sector (engineering, data science etc.), or switch STEM fields (e.g., medical school, grad school in engineering), or pursue other careers marginally related to science. The proposed B.S. in Applied Physics is intended to better prepare the latter cohort. It parallels similar degree programs at UC Davis, Rutgers University and other peer institutions.

Differences between Physics and Applied Physics: The new major will drop 18 units of required upper-division physics courses: Phys 332 (E&M 2), Phys 472 (Quantum 2), Phys 426 (Stat Mech), Phys 483 (capstone research), and two upper-division physics electives. These will be replaced with:

- One required course in oral and/or written communication
- One required course in statistics/information theory
- Two required semesters in the senior-level engineering design course (working with a team of engineers and private-sector consultants)
- Four technical electives focused on a specific target career, chosen from a variety of STEM departments. This will be done in close consultation with an advisor.

SURVEY QUESTIONS:

1. Please state your major. If you have more than one, please list all your majors and indicate which is your primary major.

2. Please state your class standing (Freshman, Sophomore, Junior or Senior, whichever is closest).

3. If the Applied Physics major were to be offered in Fall 2018, how likely are you to SWITCH to the new major? Use the following scale: 1 = very likely, 2 = somewhat likely, 3 = not sure, 4 = probably not, 5 = definitely not.

4. (If you are a physics major, skip this question.) If you are NOT a physics major, how likely are you to ADD Applied Physics as a 2nd major, in addition to your current major? Use the following scale: 1 = very likely, 2 = somewhat likely, 3 = not sure, 4 = probably not, 5 = definitely not.
5. Think back to when you were an entering Freshman shopping for majors. If Applied Physics had been one of the options, how likely would you have been to choose it as a major, instead of your current major? Use the following scale: 1 = very likely, 2 = somewhat likely, 3 = not sure, 4 = probably not, 5 = definitely not.

6. (Optional) Please add any comments you wish to share, e.g., the reasons for your above responses.
Please see the uploaded survey administered to students in several physics courses (listed below). The key question on this survey was question #5, for which responses were tabulated and counted.

**Physics course # and student responses on Question #5:**

“Think back to when you were an entering Freshman shopping for majors. If Applied Physics had been one of the options, how likely would you have been to choose it as a major, instead of your current major? Use the following scale: 1 = very likely, 2 = somewhat likely, 3 = not sure, 4 = probably not, 5 = definitely not.”

**141:** 73 students. “Would have chosen” gets 11 2’s and 8 3’s. The 2’s don’t want to switch or add, but two of the 3’s are “1” on add and on switch. (Count these two “3 + 1” votes as 2’s.) All are engineering, 7 of the 19 from ECE, mix of others.

**161H:** 27 students. “Would have chosen”: 2 1’s, 4 2’s, 4 3’s. All physics except 1 math.

**162H:** 26 students. “Would have chosen”: 3 1’s, 5 2’s, 4 3’s. All physics.

**204:** 5 students. “Would have chosen”: 2 1’s, 2 2’s. All physics.

**241:** 118 students. “Would have chosen”: 4 1’s, 20 2’s, 17 3’s. Almost all engineering, mix of majors. Only 4 or 5 would consider switching at this point.

**263H:** 10 students. “Would have chosen”: 3 1’s, 2 2’s, 1 3. All physics.

**321:** 6 students. “Would have chosen”: 4 2’s, of which 2 Astro, 2 phys

**371:** 10 students. “Would have chosen”: 2 1’s, 1 2, 3 3’s. Almost all physics.

**Calculations of student “harvest” for Applied Physics:**

Assign the following probability weights: 0.6 for 1’s, 0.3 for 2’s, 0 for 3’s and above.

Engineering harvest: 3.9 / 73 (for 141) + 8.4 / 118 (for 241) = 12.3 / 191 = 6.4%. Take 5%-7% as the range for pessimistic and optimistic scenarios.

Physics harvest: 2.4 / 27 (161H) + 3.3 / 26 (162H) + 1.8 / 5 (204) + 2.4 / 10 (263H) + 1.2 / 6 (321) + 1.5 / 10 (371) = 12.6 / 84 = 15%. Increase to 20% to account for former physics students that may have switched to other majors because there was no Applied Physics alternative.
November 6, 2017

Dr. Sumit Mazumdar:
Department Head, Physics
PO Box 210081
Building: Physics-Atmospheric Sciences (#81)

Dear Dr. Mazumdar,

I write to indicate that the Physics department can include COMM 119 (public speaking) in their proposal for an Applied Physics degree.

COMM typically has opened enrollment in COMM 119 to all students as soon as the priority registration period ends for COMM majors and minors - no special permission is required to enroll at that point. COMM cannot guarantee the Applied Physics students admission into COMM 119, but the past few years have seen a large number of COMM 119 seats available to students who are not COMM majors or minors. The key to getting a seat in COMM 119 for non COMM majors/minors is registering the day after priority registration ends, and the advising staff in Applied Physics should make students aware of the importance of moving quickly if they want a seat in Comm 119.

Good luck with your new program.

Sincerely,

Jake Harwood, Professor & Acting Department Head
jharwood@u.arizona.edu
520-626-8681
September 17, 2018

Dear Prof. Mazumdar,

The College of Engineering is happy to support the proposed new major in Applied Physics to be offered by the Department of Physics at the University of Arizona. In particular, we see no difficulties accommodating Applied Physics majors in the senior-level engineering design course, ENGR 498A and 498B. This course attracts hundreds of engineering students each year, so the anticipated 20 to 25 seniors in Applied Physics should not be an undue burden on our resources. Given the new major’s emphasis on broad fundamentals, we anticipate fruitful interactions between Applied Physics students and engineering students on each design team.

The proposed major also requires twelve (12) units of technical electives “selected to complement the student’s post-baccalaureate career interests” and anticipates that a significant fraction of Applied Physics students will choose to take at least some of these electives in the College of Engineering. Our departments offer many lower-division courses that would be accessible to Applied Physics majors (e.g. the students would have suitable prerequisites as a natural part of the Applied Physics curriculum), so enrollment in these courses should not be a problem. If a student wishes to explore upper-division engineering courses, they will first need to complete some lower-division engineering coursework. Since six (6) out of the twelve (12) elective units can be completed in lower-division courses, we anticipate that this will give students enough flexibility to lay the foundation for selected upper-division engineering courses. As the Physics Department advises individual Applied Physics students, the College of Engineering will assist the department to ensure that the Applied Physics students have the appropriate background knowledge for specific engineering courses of interest (and suitable enrollment requirements can be defined, to simply the process for the students).

We look forward to working with the Physics Department and welcome the anticipated collaborations between Applied Physics and engineering students.

Respectfully yours,

James C. Baygents, Ph.D.  
Associate Dean, Academic Affairs  
College of Engineering
Nov. 11, 2017

Sumit Mazumdar, Ph.D.
Head, Department of Physics
University of Arizona
Tucson, AZ 85721

Dear Dr. Mazumdar,

I am happy to include some of the School of Journalism’s classes in your proposed Applied Physics degree. In particular, we have the ability to offer seats in:

JOUR 472/572: Science Journalism (usually offered fall semesters)
JOUR 455/555: Environmental Journalism (usually offered spring semesters)

We have offered these classes to non-journalism majors for several years. Neither of the courses require journalism pre-requisites. We have found that the mixture of journalism and science students makes for an exciting learning environment for both. Science students learn the craft of communicating complicated subjects clearly for the public, and journalism students learn the complexities of science.

In previous years the courses usually had lots of room, although that has started to change in the past year. Last spring’s Jour 455/555 class nearly filled at 19 out of 20 available seats. This current fall semester Jour 472/572 class filled to its capacity of 20 (our skills courses are required not to exceed 20 by our national accreditors). If we see demand grow for the courses from physics students we can look at opening up additional sections, provided the school budget would allow for it.

If you have any questions, please do not hesitate to contact me.

Sincerely,

David Cuillier, Ph.D.
Director
School of Journalism
520-626-9694
cuillier@email.arizona.edu
7 November 2017

Professor Sumit Mazumdar, Head
Department of Physics
University of Arizona

Dear Professor Mazumdar:

I am writing to affirm that the Department of Physics may include ENGL 308 in its proposal for an Applied Physics degree. Below are the prerequisites and enrollment restrictions for ENGL 308:

- Foundations (First-Year) English is the only prerequisite for ENGL 308.
- The Department of English does not restrict any majors from enrolling in ENGL 308.
- The Department of English does, however, restrict enrollment in ENGL 308 based on class (juniors and seniors only) during fall and spring semesters.
- Fall and spring offerings of ENGL 308 do tend to fill after junior priority registration, and we restrict enrollment to juniors and seniors up until the week before classes before opening up registration to anyone when seats become available. Sophomores may have difficulty getting a seat in a fall or spring section of ENGL 308, but we are documenting demand and working to open more sections in future semesters.
- There are no restrictions for summer sections of ENGL 308.

Please encourage your students who take ENGL 308 to consider pursuing the Professional & Technical Writing Certificate (toward which ENGL 308 counts), which prepares students to write effectively and communicate complex information clearly. We offer an overview of the certificate, including requirements and procedures, at https://english.arizona.edu/professional-technical-writing-certificate.

Sincerely,

[Signature]

Professor Lee Medovoi, Head
Department of English
VALIDATE: EMPLOYMENT POTENTIAL

PROJECT CRITERIA

<table>
<thead>
<tr>
<th>Validate</th>
<th>Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>States</td>
<td>Arizona</td>
</tr>
<tr>
<td>Degree Level</td>
<td>Bachelor's degree</td>
</tr>
<tr>
<td>Time Period</td>
<td>12/1/2017 - 11/30/2018</td>
</tr>
<tr>
<td>Selected Programs</td>
<td>Engineering Physics/Applied Physics (14.1201)</td>
</tr>
<tr>
<td>Career Outcomes mapped to Selected Programs of Study</td>
<td>Physicist</td>
</tr>
</tbody>
</table>

HOW MANY JOBS ARE THERE FOR YOUR GRADUATES?

For your project criteria, there were 22 job postings in the last 12 months.

Compared to:

- 747,047 total job postings in your selected location
- 243,377 total job postings requesting a Bachelor's degree in your selected location

The number of jobs is expected to grow over the next 8 years.

GROWTH BY GEOGRAPHY

<table>
<thead>
<tr>
<th>Geography</th>
<th>Selected Occupations</th>
<th>Total Labor Market</th>
<th>Relative Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>12.20%</td>
<td>21.20%</td>
<td>Low</td>
</tr>
<tr>
<td>Nationwide</td>
<td>7.70%</td>
<td>6.50%</td>
<td>Average</td>
</tr>
</tbody>
</table>
HOW HAS EMPLOYMENT CHANGED FOR CAREER OUTCOMES OF YOUR PROGRAM?

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment (BLS)</td>
<td>160</td>
<td>230</td>
<td>230</td>
<td>180</td>
<td>70</td>
<td>78</td>
</tr>
</tbody>
</table>

Employment data between years 2018 and 2026 are projected figures.

DETAILS BY OCCUPATION

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and Physical Science</td>
<td>22</td>
<td>1.1</td>
<td>70</td>
<td>-61.1%</td>
<td>12.2%</td>
</tr>
</tbody>
</table>

HOW VERSATILE IS MY PROGRAM?
Graduates of this program usually transition into any of the 1 different occupation groups:

<table>
<thead>
<tr>
<th>Occupations Group</th>
<th>Market Size (postings)</th>
<th>Percentage of Career Outcome demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and Physical Science</td>
<td>22</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

**WHAT SALARY WILL MY GRADUATES MAKE?**

The average salary in Arizona for graduates of your program is $103,643. This average salary is **Above** the average living wage for Arizona of $32,531.
Salary numbers are based on Burning Glass models that consider advertised job posting salary, BLS data, and other proprietary and public sources of information.

<table>
<thead>
<tr>
<th>Occupation Group</th>
<th>25&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>Average</th>
<th>75&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and Physical Science</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
</tbody>
</table>

WHERE IS THE DEMAND FOR MY GRADUATES?

<table>
<thead>
<tr>
<th>Location</th>
<th>Postings</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>126</td>
</tr>
<tr>
<td>Texas</td>
<td>75</td>
</tr>
<tr>
<td>Maryland</td>
<td>69</td>
</tr>
<tr>
<td>Virginia</td>
<td>63</td>
</tr>
<tr>
<td>New York</td>
<td>56</td>
</tr>
<tr>
<td>State</td>
<td>Value</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>New Mexico</td>
<td>50</td>
</tr>
<tr>
<td>Washington</td>
<td>49</td>
</tr>
<tr>
<td>New Jersey</td>
<td>38</td>
</tr>
<tr>
<td>Michigan</td>
<td>37</td>
</tr>
<tr>
<td>Colorado</td>
<td>30</td>
</tr>
</tbody>
</table>
VALIDATE: COMPETITIVE LANDSCAPE

PROJECT CRITERIA

<table>
<thead>
<tr>
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<th>Programs</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Physicist</td>
</tr>
</tbody>
</table>

OVERVIEW

<table>
<thead>
<tr>
<th></th>
<th>#</th>
<th>% Change (2013-2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degrees Conferred</td>
<td>0</td>
<td>-100%</td>
</tr>
<tr>
<td>Number of Institutions</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>Average Conferrals by Institution</td>
<td>0</td>
<td>-100.00%</td>
</tr>
<tr>
<td>Median Conferrals by Institution</td>
<td>0</td>
<td>-100.00%</td>
</tr>
</tbody>
</table>
MARKET SHARE BY PROGRAM

Engineering Physics/Applied Physics (0%)

Program | Conferrals (2017) | Market Share (%) |
---------|------------------|------------------|
Engineering Physics/Applied Physics | 0 | 0.00% |

MARKET SHARE BY INSTITUTION TYPE
Institution Type

<table>
<thead>
<tr>
<th>Institution Type</th>
<th>Conferrals (2017)</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

TOP 10 INSTITUTIONS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Arizona University</td>
<td>Public</td>
<td>0.00%</td>
<td>-100.00%</td>
<td></td>
<td>-100.00%</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>Public</td>
<td>NaN%</td>
<td>NaN%</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

TOP 10 PROGRAMS
### ACTIVE COMPETITORS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Illinois</td>
<td>Public</td>
<td>73.75%</td>
<td>16.61%</td>
<td>59</td>
<td>110.70%</td>
</tr>
<tr>
<td>at Urbana-Champaign</td>
<td>Public</td>
<td>25.00%</td>
<td>-3.57%</td>
<td>20</td>
<td>42.90%</td>
</tr>
<tr>
<td>Ohio State University-Main</td>
<td>Public</td>
<td>1.25%</td>
<td>-6.91%</td>
<td>1</td>
<td>-75.00%</td>
</tr>
<tr>
<td>Campus</td>
<td>Public</td>
<td>0.00%</td>
<td>-6.12%</td>
<td></td>
<td>-100.00%</td>
</tr>
<tr>
<td>Northern Arizona University</td>
<td>Public</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
<td>0.00%</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>Public</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
<td>0.00%</td>
</tr>
</tbody>
</table>
VALIDATE: MARKET ALIGNMENT

PROJECT CRITERIA

<table>
<thead>
<tr>
<th>Explore</th>
<th>Programs</th>
</tr>
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<tbody>
<tr>
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</tbody>
</table>

JOB POSTINGS BY ADVERTISED EDUCATION (%)
TOP TITLES

**Experience Level:** All Experience

<table>
<thead>
<tr>
<th>Title</th>
<th>Postings</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicist</td>
<td>14</td>
<td>87.50%</td>
</tr>
<tr>
<td>Devops With Cloud</td>
<td>1</td>
<td>6.25%</td>
</tr>
<tr>
<td>Technical Specialist</td>
<td>1</td>
<td>6.25%</td>
</tr>
</tbody>
</table>

TOP EMPLOYERS HIRING

**Experience Level:** All Experience
<table>
<thead>
<tr>
<th>Employer</th>
<th>Postings</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayo Foundation for Medical Education and Research</td>
<td>8</td>
<td>50.00%</td>
</tr>
<tr>
<td>Raytheon</td>
<td>4</td>
<td>25.00%</td>
</tr>
<tr>
<td>Camris International</td>
<td>2</td>
<td>12.50%</td>
</tr>
<tr>
<td>Datalysys</td>
<td>1</td>
<td>6.25%</td>
</tr>
<tr>
<td>IBM</td>
<td>1</td>
<td>6.25%</td>
</tr>
</tbody>
</table>
## VALIDATE: KEY COMPETENCIES

### PROJECT CRITERIA

<table>
<thead>
<tr>
<th>Validate</th>
<th>Programs</th>
</tr>
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</tr>
</tbody>
</table>

### TOP 15 SPECIALIZED SKILLS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Projected Growth</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>16 (73%)</td>
<td>-23.81%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Teaching</td>
<td>15 (68%)</td>
<td>-9.15%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Field</td>
<td>Count (%)</td>
<td>Change (%)</td>
<td>Required</td>
<td>For Hire</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Medical Physics</td>
<td>8 (36%)</td>
<td>28.34%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Radiology</td>
<td>6 (27%)</td>
<td>26.39%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Interaction with Patients / Medical Personnel</td>
<td>6 (27%)</td>
<td>-3.61%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>MATLAB</td>
<td>5 (23%)</td>
<td>-5.89%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Threat Hunting</td>
<td>4 (18%)</td>
<td>291.15%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>System Architecture</td>
<td>4 (18%)</td>
<td>6.4%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Requirements Verification and Validation</td>
<td>4 (18%)</td>
<td>-11.88%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Materials Selection</td>
<td>4 (18%)</td>
<td>-12.69%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Engineering Leadership</td>
<td>4 (18%)</td>
<td>27.81%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Employee Training</td>
<td>4 (18%)</td>
<td>-9.17%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Electro-Optical Systems</td>
<td>4 (18%)</td>
<td>11.24%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>C++</td>
<td>4 (18%)</td>
<td>-25.85%</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Anomaly Detection | 4 (18%) | 72.86% | No | No

### TOP 15 BASELINES SKILLS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamwork / Collaboration</td>
<td>12 (55%)</td>
</tr>
<tr>
<td>Communication Skills</td>
<td>11 (50%)</td>
</tr>
<tr>
<td>Research</td>
<td>9 (41%)</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>7 (32%)</td>
</tr>
<tr>
<td>Verbal / Oral Communication</td>
<td>5 (23%)</td>
</tr>
<tr>
<td>Writing</td>
<td>4 (18%)</td>
</tr>
<tr>
<td>Leadership</td>
<td>4 (18%)</td>
</tr>
<tr>
<td>Skill</td>
<td>Postings</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Mentoring</td>
<td>4 (18%)</td>
</tr>
<tr>
<td>Microsoft Office</td>
<td>4 (18%)</td>
</tr>
<tr>
<td>Analytical Skills</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Detail-Oriented</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Time Management</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Building Effective Relationships</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Persuasion</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Skill Cluster</td>
<td>Percentage</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>MATLAB</td>
<td>5 (23%)</td>
</tr>
<tr>
<td>C++</td>
<td>4 (18%)</td>
</tr>
<tr>
<td>Microsoft Office</td>
<td>4 (18%)</td>
</tr>
<tr>
<td>IBM Cloud</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>OpenShift</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Python</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Linux</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>LabVIEW</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Java</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Computer Engineering</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Youtube</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Skill</td>
<td>Postings</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Oncology</td>
<td>9 (41%)</td>
</tr>
<tr>
<td>System Design and Implementation</td>
<td>7 (32%)</td>
</tr>
<tr>
<td>Radiology</td>
<td>6 (27%)</td>
</tr>
<tr>
<td>C and C++</td>
<td>4 (18%)</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Network Protocols</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Quality Assurance and Control</td>
<td>2 (9%)</td>
</tr>
<tr>
<td>Software Development Methodologies</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Operating Systems</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Product Development</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Software Development Principles</td>
<td>1 (5%)</td>
</tr>
</tbody>
</table>
Report generated using Program Insight from Burning Glass Technologies

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Projected Growth</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation Therapy</td>
<td>2 (9%)</td>
<td>18.81%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>DevOps</td>
<td>1 (5%)</td>
<td>87.97%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>1 (5%)</td>
<td>4.8%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Linux</td>
<td>1 (5%)</td>
<td>-7.6%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Product Development</td>
<td>1 (5%)</td>
<td>-18.93%</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
## TOP 15 COMPETITIVE ADVANTAGE SKILLS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Projected Growth</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>C++</td>
<td>4 (18%)</td>
<td>-25.85%</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Quality Assurance and Control</td>
<td>2 (9%)</td>
<td>1.97%</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>1 (5%)</td>
<td>4.8%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

## TOP 15 CERTIFICATIONS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Board of Radiology (ABR)</td>
<td>6 (27%)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Security Clearance</td>
<td>4 (18%)</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

## TOP 15 SALARY PREMIUM CERTIFICATIONS
<table>
<thead>
<tr>
<th>Security Clearance</th>
<th>4 (18%)</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

**TOP 15 COMPETITIVE ADVANTAGE CERTIFICATIONS**

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Board of Radiology (ABR)</td>
<td>6 (27%)</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
VALIDATE: EMPLOYMENT POTENTIAL

PROJECT CRITERIA

<table>
<thead>
<tr>
<th>Validate</th>
<th>Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Nationwide</td>
</tr>
<tr>
<td>Degree Level</td>
<td>Bachelor’s degree</td>
</tr>
<tr>
<td>Time Period</td>
<td>12/1/2017 - 11/30/2018</td>
</tr>
<tr>
<td>Selected Programs</td>
<td>Engineering Physics/Applied Physics (14.1201)</td>
</tr>
<tr>
<td>Career Outcomes mapped to Selected Programs of Study</td>
<td>Physicist</td>
</tr>
</tbody>
</table>

HOW MANY JOBS ARE THERE FOR YOUR GRADUATES?

For your project criteria, there were 1,030 job postings in the last 12 months.

Compared to:

- 27,390,966 total job postings in your selected location
- 9,916,530 total job postings requesting a Bachelor's degree in your selected location

The number of jobs is expected to grow over the next 8 years.

GROWTH BY GEOGRAPHY

<table>
<thead>
<tr>
<th>Geography</th>
<th>Selected Occupations</th>
<th>Total Labor Market</th>
<th>Relative Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nationwide</td>
<td>7.70%</td>
<td>6.50%</td>
<td>Average</td>
</tr>
</tbody>
</table>
HOW HAS EMPLOYMENT CHANGED FOR CAREER OUTCOMES OF YOUR PROGRAM?

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment (BLS)</td>
<td>17,820</td>
<td>17,340</td>
<td>16,790</td>
<td>15,650</td>
<td>16,680</td>
<td>17,964</td>
</tr>
</tbody>
</table>

Employment data between years 2018 and 2026 are projected figures.

DETAILS BY OCCUPATION

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and Physical Science</td>
<td>1,030</td>
<td>NA</td>
<td>16,680</td>
<td>6.6%</td>
<td>7.7%</td>
</tr>
</tbody>
</table>

HOW VERSATILE IS MY PROGRAM?

Graduates of this program usually transition into any of the 1 different occupation groups:
WHAT SALARY WILL MY GRADUATES MAKE?

The average salary in the nation for graduates of your program is $95,153. This average salary is Above the average living wage for the nation of $31,450.

<table>
<thead>
<tr>
<th>Occupations Group</th>
<th>Market Size (postings)</th>
<th>Percentage of Career Outcome demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and Physical Science</td>
<td>1,030</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Salary numbers are based on Burning Glass models that consider advertised job posting salary, BLS data, and other proprietary and public sources of information.

<table>
<thead>
<tr>
<th>Occupation Group</th>
<th>25th Percentile</th>
<th>Average</th>
<th>75th Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and Physical Science</td>
<td>$91,305</td>
<td>$97,714</td>
<td>$103,637</td>
</tr>
</tbody>
</table>

WHERE IS THE DEMAND FOR MY GRADUATES?

TOP LOCATIONS BY POSTING DEMAND

<table>
<thead>
<tr>
<th>Location</th>
<th>Postings</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>126</td>
</tr>
<tr>
<td>Texas</td>
<td>75</td>
</tr>
<tr>
<td>Maryland</td>
<td>69</td>
</tr>
<tr>
<td>Virginia</td>
<td>63</td>
</tr>
<tr>
<td>New York</td>
<td>56</td>
</tr>
<tr>
<td>State</td>
<td>Value</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>New Mexico</td>
<td>50</td>
</tr>
<tr>
<td>Washington</td>
<td>49</td>
</tr>
<tr>
<td>New Jersey</td>
<td>38</td>
</tr>
<tr>
<td>Michigan</td>
<td>37</td>
</tr>
<tr>
<td>Colorado</td>
<td>30</td>
</tr>
</tbody>
</table>
# VALIDATE: COMPETITIVE LANDSCAPE

## PROJECT CRITERIA

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Validate</td>
<td>Programs</td>
</tr>
<tr>
<td>Location</td>
<td>Nationwide</td>
</tr>
<tr>
<td>Degree Level</td>
<td>Bachelor's degree</td>
</tr>
<tr>
<td>Time Period</td>
<td>12/1/2017 - 11/30/2018</td>
</tr>
<tr>
<td>Selected Programs</td>
<td>Engineering Physics/Applied Physics (14.1201)</td>
</tr>
<tr>
<td>Career Outcomes mapped to Selected Programs of Study</td>
<td>Physicist</td>
</tr>
</tbody>
</table>

## OVERVIEW

<table>
<thead>
<tr>
<th></th>
<th>#</th>
<th>% Change (2013-2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degrees Conferred</td>
<td>615</td>
<td>32%</td>
</tr>
<tr>
<td>Number of Institutions</td>
<td>112</td>
<td>8%</td>
</tr>
<tr>
<td>Average Conferrals by Institution</td>
<td>5</td>
<td>0.00%</td>
</tr>
<tr>
<td>Median Conferrals by Institution</td>
<td>3</td>
<td>50.00%</td>
</tr>
</tbody>
</table>
MARKET SHARE BY PROGRAM

<table>
<thead>
<tr>
<th>Program</th>
<th>Conferrals (2017)</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Physics/Applied Physics</td>
<td>615</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

MARKET SHARE BY INSTITUTION TYPE
Institution Type

<table>
<thead>
<tr>
<th>Institution Type</th>
<th>Conferrals (2017)</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For-Profit</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Private</td>
<td>280</td>
<td>45.53%</td>
</tr>
<tr>
<td>Public</td>
<td>335</td>
<td>54.47%</td>
</tr>
</tbody>
</table>

**TOP 10 INSTITUTIONS**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Illinois at Urbana-Champaign</td>
<td>Public</td>
<td>9.59%</td>
<td>3.58%</td>
<td>59</td>
<td>110.70%</td>
</tr>
<tr>
<td>Colorado School of Mines</td>
<td>Public</td>
<td>9.11%</td>
<td>-0.76%</td>
<td>56</td>
<td>21.70%</td>
</tr>
<tr>
<td>Murray State University</td>
<td>Public</td>
<td>4.39%</td>
<td>1.81%</td>
<td>27</td>
<td>125.00%</td>
</tr>
</tbody>
</table>
## TOP 10 PROGRAMS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Physics/Applied Physics</td>
<td>100.00%</td>
<td>0.00%</td>
<td>615</td>
<td>32.00%</td>
</tr>
</tbody>
</table>

## ACTIVE COMPETITORS
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Illinois at Urbana-Champaign</td>
<td>Public</td>
<td>73.75%</td>
<td>16.61%</td>
<td>59</td>
<td>110.70%</td>
</tr>
<tr>
<td>Ohio State University-Main Campus</td>
<td>Public</td>
<td>25.00%</td>
<td>-3.57%</td>
<td>20</td>
<td>42.90%</td>
</tr>
<tr>
<td>University of Wisconsin-Madison</td>
<td>Public</td>
<td>1.25%</td>
<td>-6.91%</td>
<td>1</td>
<td>-75.00%</td>
</tr>
<tr>
<td>Northern Arizona University</td>
<td>Public</td>
<td>0.00%</td>
<td>-6.12%</td>
<td>0</td>
<td>-100.00%</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>Public</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
VALIDATE: MARKET ALIGNMENT

PROJECT CRITERIA

<table>
<thead>
<tr>
<th>Explore</th>
<th>Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Nationwide</td>
</tr>
<tr>
<td>Degree Level</td>
<td>Bachelor's degree</td>
</tr>
<tr>
<td>Time Period</td>
<td>12/1/2017 - 11/30/2018</td>
</tr>
<tr>
<td>Selected Programs</td>
<td>Engineering Physics/Applied Physics (14.1201)</td>
</tr>
<tr>
<td>Career Outcomes mapped to Selected Programs of Study</td>
<td>Physicist</td>
</tr>
</tbody>
</table>

JOB POSTINGS BY ADVERTISED EDUCATION (%)
TOP TITLES

**Experience Level:** All Experience

<table>
<thead>
<tr>
<th>Title</th>
<th>Postings</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicist</td>
<td>500</td>
<td>65.27%</td>
</tr>
<tr>
<td>Technical Specialist</td>
<td>14</td>
<td>1.83%</td>
</tr>
<tr>
<td>Molecular Technician</td>
<td>13</td>
<td>1.70%</td>
</tr>
<tr>
<td>Cloud First - Salesforce</td>
<td>9</td>
<td>1.17%</td>
</tr>
<tr>
<td>Technical Architect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Scientist, Physics</td>
<td>9</td>
<td>1.17%</td>
</tr>
<tr>
<td>Cloud Engineering Devops Architect</td>
<td>7</td>
<td>0.91%</td>
</tr>
<tr>
<td>Job Title</td>
<td>Postings</td>
<td>Market Share (%)</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-----------</td>
<td>------------------</td>
</tr>
<tr>
<td>Cloud Technical Expert</td>
<td>7</td>
<td>0.91%</td>
</tr>
<tr>
<td>Cloud Devops</td>
<td>5</td>
<td>0.65%</td>
</tr>
<tr>
<td>Cloud Isso</td>
<td>5</td>
<td>0.65%</td>
</tr>
<tr>
<td>Computational Dynamicist</td>
<td>5</td>
<td>0.65%</td>
</tr>
<tr>
<td>Mass Spectrometry Specialist</td>
<td>5</td>
<td>0.65%</td>
</tr>
<tr>
<td>Specialist</td>
<td>5</td>
<td>0.65%</td>
</tr>
<tr>
<td>Cloud</td>
<td>4</td>
<td>0.52%</td>
</tr>
<tr>
<td>Cloud Transformation &amp; Migration Cons</td>
<td>4</td>
<td>0.52%</td>
</tr>
<tr>
<td>Devops, Cloud, Microservices, Aws, Ec2 Docker, , Git, Ruby</td>
<td>4</td>
<td>0.52%</td>
</tr>
</tbody>
</table>

**TOP EMPLOYERS HIRING**

**Experience Level:** All Experience

<table>
<thead>
<tr>
<th>Employer</th>
<th>Postings</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Government</td>
<td>24</td>
<td>3.13%</td>
</tr>
<tr>
<td>US Air Force</td>
<td>20</td>
<td>2.61%</td>
</tr>
<tr>
<td>US Navy</td>
<td>18</td>
<td>2.35%</td>
</tr>
<tr>
<td>Accenture</td>
<td>14</td>
<td>1.83%</td>
</tr>
<tr>
<td>IBM</td>
<td>14</td>
<td>1.83%</td>
</tr>
<tr>
<td>Department Army</td>
<td>12</td>
<td>1.57%</td>
</tr>
<tr>
<td>Organization</td>
<td>Count</td>
<td>Percentage</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>US Department of Commerce</td>
<td>12</td>
<td>1.57%</td>
</tr>
<tr>
<td>Department of Veterans Affairs</td>
<td>11</td>
<td>1.44%</td>
</tr>
<tr>
<td>Mayo Foundation for Medical Education and Research</td>
<td>11</td>
<td>1.44%</td>
</tr>
<tr>
<td>Jacobs Engineering Group Incorporated</td>
<td>9</td>
<td>1.17%</td>
</tr>
<tr>
<td>Michigan State University</td>
<td>9</td>
<td>1.17%</td>
</tr>
<tr>
<td>Indiana University</td>
<td>8</td>
<td>1.04%</td>
</tr>
<tr>
<td>Leidos</td>
<td>8</td>
<td>1.04%</td>
</tr>
<tr>
<td>Los Alamos National Laboratory</td>
<td>8</td>
<td>1.04%</td>
</tr>
<tr>
<td>Microsoft Corporation</td>
<td>8</td>
<td>1.04%</td>
</tr>
</tbody>
</table>
VALIDATE: KEY COMPETENCIES

PROJECT CRITERIA

<table>
<thead>
<tr>
<th>Validate</th>
<th>Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
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</tr>
</tbody>
</table>

TOP 15 SPECIALIZED SKILLS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Projected Growth</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>672 (65%)</td>
<td>-23.81%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Medical Physics</td>
<td>141 (14%)</td>
<td>28.34%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Field</td>
<td>Count (%)</td>
<td>Change (%)</td>
<td>Requirement</td>
<td>Non-Requirement</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-----------</td>
<td>------------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Chemistry</td>
<td>141 (14%)</td>
<td>-21.4%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Radiation Protection</td>
<td>132 (13%)</td>
<td>5.58%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Medical Dosimetry</td>
<td>114 (11%)</td>
<td>50.79%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>DevOps</td>
<td>110 (11%)</td>
<td>87.97%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Biology</td>
<td>108 (10%)</td>
<td>-26.71%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Quality Assurance and Control</td>
<td>104 (10%)</td>
<td>1.97%</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ionizing Radiation</td>
<td>102 (10%)</td>
<td>13.82%</td>
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<td>No</td>
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<tr>
<td>Cloud architecture</td>
<td>93 (9%)</td>
<td>106.16%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Python</td>
<td>85 (8%)</td>
<td>68.28%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Linux</td>
<td>83 (8%)</td>
<td>-7.6%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Radiation Oncology</td>
<td>83 (8%)</td>
<td>19.47%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Calculus</td>
<td>83 (8%)</td>
<td>-25.39%</td>
<td>No</td>
<td>No</td>
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</tbody>
</table>
### TOP 15 BASELINES SKILLS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>355 (34%)</td>
</tr>
<tr>
<td>Communication Skills</td>
<td>247 (24%)</td>
</tr>
<tr>
<td>Teamwork / Collaboration</td>
<td>182 (18%)</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>168 (16%)</td>
</tr>
<tr>
<td>Writing</td>
<td>150 (15%)</td>
</tr>
<tr>
<td>Planning</td>
<td>146 (14%)</td>
</tr>
<tr>
<td>Written Communication</td>
<td>93 (9%)</td>
</tr>
<tr>
<td>Skill</td>
<td>Postings</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Troubleshooting</td>
<td>87 (8%)</td>
</tr>
<tr>
<td>Microsoft Office</td>
<td>84 (8%)</td>
</tr>
<tr>
<td>Detail-Oriented</td>
<td>66 (6%)</td>
</tr>
<tr>
<td>Building Effective Relationships</td>
<td>57 (6%)</td>
</tr>
<tr>
<td>Physical Abilities</td>
<td>57 (6%)</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>56 (5%)</td>
</tr>
<tr>
<td>Organizational Skills</td>
<td>52 (5%)</td>
</tr>
<tr>
<td>Microsoft Excel</td>
<td>51 (5%)</td>
</tr>
<tr>
<td>Technology</td>
<td>Popularity (%)</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Python</td>
<td>85 (8%)</td>
</tr>
<tr>
<td>Microsoft Office</td>
<td>84 (8%)</td>
</tr>
<tr>
<td>Linux</td>
<td>83 (8%)</td>
</tr>
<tr>
<td>Java</td>
<td>72 (7%)</td>
</tr>
<tr>
<td>Software Development</td>
<td>68 (7%)</td>
</tr>
<tr>
<td>IBM Cloud</td>
<td>61 (6%)</td>
</tr>
<tr>
<td>SQL</td>
<td>61 (6%)</td>
</tr>
<tr>
<td>Platform as a Service (PaaS)</td>
<td>55 (5%)</td>
</tr>
<tr>
<td>Puppet</td>
<td>53 (5%)</td>
</tr>
<tr>
<td>Software as a Service (SaaS)</td>
<td>53 (5%)</td>
</tr>
<tr>
<td>Microsoft Excel</td>
<td>51 (5%)</td>
</tr>
<tr>
<td>Oracle</td>
<td>46 (4%)</td>
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### TOP 15 SKILL CLUSTERS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiology</td>
<td>292 (28%)</td>
</tr>
<tr>
<td>Oncology</td>
<td>239 (23%)</td>
</tr>
<tr>
<td>System Design and Implementation</td>
<td>176 (17%)</td>
</tr>
<tr>
<td>Project Management</td>
<td>130 (13%)</td>
</tr>
<tr>
<td>Software Development Methodologies</td>
<td>124 (12%)</td>
</tr>
<tr>
<td>Quality Assurance and Control</td>
<td>124 (12%)</td>
</tr>
</tbody>
</table>

Report generated using Program Insight from Burning Glass Technologies
## People Management

- **Posts**: 122 (12%)

## Software Development Principles

- **Posts**: 111 (11%)

## Operating Systems

- **Posts**: 100 (10%)

## Database Administration

- **Posts**: 81 (8%)

## Data Analysis

- **Posts**: 76 (7%)

## Simulation

- **Posts**: 52 (5%)

## Oracle

- **Posts**: 46 (4%)

## Network Protocols

- **Posts**: 38 (4%)

## C and C++

- **Posts**: 30 (3%)

### TOP 15 SALARY PREMIUM SKILLS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Projected Growth</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Category</td>
<td>Count</td>
<td>Percentage</td>
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<tr>
<td>---------------------------</td>
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<td>------------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>Radiation Protection</td>
<td>132</td>
<td>13%</td>
<td>5.58%</td>
<td>Yes</td>
</tr>
<tr>
<td>Medical Dosimetry</td>
<td>114</td>
<td>11%</td>
<td>50.79%</td>
<td>Yes</td>
</tr>
<tr>
<td>DevOps</td>
<td>110</td>
<td>11%</td>
<td>87.97%</td>
<td>Yes</td>
</tr>
<tr>
<td>Linux</td>
<td>83</td>
<td>8%</td>
<td>-7.6%</td>
<td>Yes</td>
</tr>
<tr>
<td>Personnel Management</td>
<td>73</td>
<td>7%</td>
<td>-30%</td>
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<td>Software Development</td>
<td>68</td>
<td>7%</td>
<td>2.33%</td>
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<tr>
<td>Radiation Therapy</td>
<td>64</td>
<td>6%</td>
<td>18.81%</td>
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<tr>
<td>Data Analysis</td>
<td>62</td>
<td>6%</td>
<td>4.8%</td>
<td>Yes</td>
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<tr>
<td>Project Management</td>
<td>61</td>
<td>6%</td>
<td>-16.48%</td>
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<tr>
<td>Simulation</td>
<td>51</td>
<td>5%</td>
<td>9.57%</td>
<td>Yes</td>
</tr>
<tr>
<td>Oracle</td>
<td>46</td>
<td>4%</td>
<td>-1.63%</td>
<td>Yes</td>
</tr>
<tr>
<td>Product Development</td>
<td>24</td>
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<td>-18.93%</td>
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### SSL

<table>
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<th>Salary Premium</th>
<th>Competitive Advantage</th>
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<tr>
<td>8 (1%)</td>
<td>23.11%</td>
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<td>No</td>
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### Hardware Experience

<table>
<thead>
<tr>
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<th>Salary Premium</th>
<th>Competitive Advantage</th>
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<tr>
<td>5 (0%)</td>
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### Prototyping

<table>
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<th>Competitive Advantage</th>
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<td>2 (0%)</td>
<td>3.49%</td>
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<td>No</td>
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### TOP 15 COMPETITIVE ADVANTAGE SKILLS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Projected Growth</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Dosimetry</td>
<td>114 (11%)</td>
<td>50.79%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Quality Assurance and Control</td>
<td>104 (10%)</td>
<td>1.97%</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>62 (6%)</td>
<td>4.8%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Project Management</td>
<td>61 (6%)</td>
<td>-16.48%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Simulation</td>
<td>51 (5%)</td>
<td>9.57%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Oracle</td>
<td>46 (4%)</td>
<td>-1.63%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Skill</td>
<td>Postings</td>
<td>Salary Premium</td>
<td>Competitive Advantage</td>
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<tr>
<td>---------------------------</td>
<td>----------</td>
<td>----------------</td>
<td>-----------------------</td>
<td></td>
</tr>
<tr>
<td>Configuration Management</td>
<td>40 (4%)</td>
<td>11.79%</td>
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<tr>
<td>C++</td>
<td>29 (3%)</td>
<td>-25.85%</td>
<td>No</td>
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<tr>
<td>Oncology</td>
<td>16 (2%)</td>
<td>53.25%</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Product Sales</td>
<td>6 (1%)</td>
<td>-6.18%</td>
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<tr>
<td>IBM WEBSPHERE</td>
<td>1 (0%)</td>
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**TOP 15 CERTIFICATIONS**
<table>
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<tr>
<th>Certification</th>
<th>Percentage</th>
<th>Employed</th>
<th>Non-Employed</th>
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<tbody>
<tr>
<td>Certified Health Physicist</td>
<td>35 (3%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Project Management Certification</td>
<td>28 (3%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>American Board for Engineering and Technology (ABET) Accredited</td>
<td>11 (1%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Radiation Safety Certified</td>
<td>10 (1%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Radiation Safety Certification</td>
<td>10 (1%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Welding Certification</td>
<td>8 (1%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>American Registry of Radiologic Technologists (ARRT) Certification</td>
<td>8 (1%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>American Society For Clinical Pathology (ASCP) Certification</td>
<td>7 (1%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Vocational Rehabilitation License</td>
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<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Certified Nuclear Medicine Technologist</td>
<td>5 (0%)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ITIL Certification</td>
<td>5 (0%)</td>
<td>No</td>
<td>No</td>
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</table>
### TOP 15 SALARY PREMIUM CERTIFICATIONS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security Clearance</td>
<td>107 (10%)</td>
<td>Yes</td>
<td>No</td>
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</table>

### TOP 15 COMPETITIVE ADVANTAGE CERTIFICATIONS

<table>
<thead>
<tr>
<th>Skill</th>
<th>Postings</th>
<th>Salary Premium</th>
<th>Competitive Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Board of Radiology (ABR)</td>
<td>73 (7%)</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
## UA Applied Physics at Micro-campus - Hebei University of Technology

<table>
<thead>
<tr>
<th><strong>Partner Snapshot</strong></th>
<th><strong>Location</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hebei University of Technology</td>
<td>Tianjin, China</td>
</tr>
</tbody>
</table>

**Founded:** 1903 – Public Institution

**Accredited by:**
- Ministry of Education; State Education Commission

**Launch Date:** Fall 2020

**Degrees:**
- BS in Applied Physics
- BS in Materials Science and Engineering
- BS in Mechanical Engineering

**Minimum Cohort:**
- 120 students per year per degree
- 1,200 minimum total at full operation

**Students, Academics, Research, Other:**
- 25,000 students – 2,577 Faculty
- National Engineering Research Center
- 17 Research Institutes

**Teaching Methodology:** In-person; flipped

**Tuition:** $5500 to UA/per year

**5Y Min Expected Net Rev:** $6,580,500

**Rankings and Distinctions:**
- Highest university entry exam scores in province
- Part of “Project 211,” national project that distributes funds to select universities; marker of top 100 universities in China
- Member of “Double First Class” plan, national project to develop world-class universities

**Campus Visits:**
- UA leadership visited HEBUT six times between Sept. 2017 and Dec. 2018;
- Interim SVP for Academic Affairs and Provost and Vice Provost for Global Affairs visited in 2018; HEBUT leaders visited UA in 2017 and 2018

---

**ABOUT HEBUT & STRATEGIC RATIONALE FOR AN UNDERGRADUATE DEGREE IN APPLIED PHYSICS**

Hebei University of Technology (HEBUT) is a public research university with 25,000 students, 20 schools, and 70 departments — ranging from Science and Engineering to Humanities and Laws. Jointly sponsored by the Chinese Ministry of Education, Hebei Province Department of Education, and Tianjin City, HEBUT’s required college entry exam score is the highest of all universities in Hebei Province. HEBUT is known as a leading industry and technology institution.

HEBUT has 2,577 faculty members, of whom 1,473 are full-time faculty; 817 hold senior professional titles, and several hold distinctions and recognitions. HEBUT has an exceptional team of national technology expertise, 3 state-level teaching teams, 2 innovative research teams with the Ministry of Education, a state-level top professor, and 5 provincial teaching teams. 187 staff members have won provincial and ministerial level honors and provide outstanding services and support to their student population. There are 240 current Applied Physics undergraduate students in HEBUT, and they expect a minimum growth of approximately 50% more students seeking this degree through the dual degree program with the UA.
HEBUT is a member of the Chinese Ministry of Education “Project 211,” whereby money is distributed to universities to raise research standards and cultivate economic development strategies. Membership in “Project 211” is a marker of the top 100 universities in China. Most recently, HEBUT was included in the “Double First Class” plan, a national initiative to establish first-rate universities and disciplines.

Like the UA, international education is a pillar of HEBUT’s strategic plan, and establishing a micro-campus is a top priority. The project has the backing of Hebei’s provincial government along with the governor himself. Internally, HEBUT has formed a special committee and task force to oversee and implement the collaboration with the UA. As added background, micro-campus discussions originated with Materials Science and Engineering professor Srinivasa Raghavan who spends his summers teaching and conducting joint research projects at HEBUT.

**ACADEMIC PROGRAMS AND STATUS:**

The micro-campus with HEBUT has been approved for a Fall 2020 launch with three dual degree programs: a BS in Materials Science & Engineering, a BS in Mechanical Engineering, and the BS in Applied Physics. The UA will teach a minimum of 45 credits for each degree program. UA CESL coursework will be provided in years one and two, and students must earn CESL endorsement to enroll as degree-seeking UA students.

Instruction will be provided through a flipped classroom model, with UA faculty on the ground to lead in class discussions. This is the same model of our successful location at Ocean University of China in Qingdao where we have 5 full-time faculty members (non-tenure tracked Global Professors) and offer some short courses with full-time tenure or tenure-tracked faculty from the UA.

While this model is costlier than the typical partner-provided co-professor model, it is the only model that works in China due to the Chinese Ministry of Education’s (MOE) regulations and market expectations. It is financially feasible and worthwhile due to the size of the program. Having on the ground professors also provides the UA with direct control over all UA courses.

The UA and HEBUT applied for MOE approval of the dual degree and partnership last fall 2018, and provost Goldberg visited China along with other college and UA Global leadership for the defense of the application. At this time, UA Global is addressing requests for additional information from the MOE and expects to have the revisions and added information submitted within this month of March.
## BUDGET – APPLIED PHYSICS ONLY

<table>
<thead>
<tr>
<th>Net tuition:</th>
<th>$ 11,000.00</th>
<th>AY Shared Tuition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FY2019</td>
<td>FY2020</td>
</tr>
<tr>
<td><strong>Student Counts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS Applied Physics</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td><strong>Total Student Enrollment</strong></td>
<td>120</td>
<td>240</td>
</tr>
</tbody>
</table>

| **OPERATING REVENUES**  |         |         |        |        |        |
| BS Applied Physics      | 660,000 | 1,320,000 | 1,980,000 | 2,640,000 | 2,640,000 |
| **TOTAL - OPERATING REVENUES** | 660,000 | 1,320,000 | 1,980,000 | 2,640,000 | 2,640,000 |

| **OPERATING EXPENSES**  |         |         |        |        |        |
| Course Build-out/Design/Refresh | 66,000 | 66,000 | 39,600 | 52,800 | 52,800 |
| Instructional Costs      | 231,000 | 462,000 | 693,000 | 924,000 | 924,000 |
| Student Support          | 39,600  | 79,200  | 118,800 | 158,400 | 158,400 |
| ERE                      | 103,700 | 184,300 | 255,700 | 341,000 | 341,000 |
| Overhead Support         | 99,000  | 132,000 | 198,000 | 264,000 | 264,000 |
| Travel                   | 66,000  | 66,000  | 69,300  | 79,200  | 79,200  |
| **TOTAL - OPERATING EXPENSES** | 605,300 | 989,500 | 1,374,400 | 1,819,400 | 1,819,400 |

| **NET POSITION**         |         |         |        |        |        |
|                         | 54,700  | 330,500 | 605,600 | 820,600 | 820,600 |

| **CUMULATIVE NET REVENUE** | $2,632,000.00 |

THE UNIVERSITY OF ARIZONA | UA Global
## BUDGET – MICRO-CAMPUS PROJECTIONS

<table>
<thead>
<tr>
<th>Net tuition:</th>
<th>$11,000.00</th>
<th>AY Shared Tuition</th>
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<tr>
<td></td>
<td>FY2019</td>
<td>FY2020</td>
</tr>
<tr>
<td><strong>Student Counts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS Mechanical Engineering</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>BS Applied Physics</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>BS Materials Science &amp; Engineering</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td><strong>Total Student Enrollment</strong></td>
<td><strong>360</strong></td>
<td><strong>720</strong></td>
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<table>
<thead>
<tr>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>BS Mechanical Engineering</td>
<td>660,000</td>
<td>1,320,000</td>
<td>1,980,000</td>
<td>2,640,000</td>
<td>2,640,000</td>
</tr>
<tr>
<td>BS Applied Physics</td>
<td>660,000</td>
<td>1,320,000</td>
<td>1,980,000</td>
<td>2,640,000</td>
<td>2,640,000</td>
</tr>
<tr>
<td>BS Materials Science &amp; Engineering</td>
<td>660,000</td>
<td>1,320,000</td>
<td>1,980,000</td>
<td>2,640,000</td>
<td>2,640,000</td>
</tr>
<tr>
<td><strong>TOTAL - OPERATING REVENUES</strong></td>
<td><strong>1,980,000</strong></td>
<td><strong>3,960,000</strong></td>
<td><strong>5,940,000</strong></td>
<td><strong>7,920,000</strong></td>
<td><strong>7,920,000</strong></td>
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</tbody>
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<table>
<thead>
<tr>
<th>OPERATING EXPENSES</th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Course Build-out/Design/Refresh</td>
<td>198,000</td>
<td>198,000</td>
<td>118,800</td>
<td>158,400</td>
<td>158,400</td>
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<tr>
<td>Instructional Costs</td>
<td>693,000</td>
<td>1,386,000</td>
<td>2,079,000</td>
<td>2,772,000</td>
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<tr>
<td>Student Support</td>
<td>118,800</td>
<td>237,600</td>
<td>356,400</td>
<td>475,200</td>
<td>475,200</td>
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<tr>
<td>ERE</td>
<td>311,000</td>
<td>552,900</td>
<td>767,100</td>
<td>1,022,800</td>
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<tr>
<td>Overhead Support</td>
<td>297,000</td>
<td>396,000</td>
<td>594,000</td>
<td>792,000</td>
<td>792,000</td>
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<tr>
<td>Travel</td>
<td>198,000</td>
<td>198,000</td>
<td>207,900</td>
<td>237,600</td>
<td>237,600</td>
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<tr>
<td><strong>TOTAL - OPERATING EXPENSES</strong></td>
<td><strong>1,815,800</strong></td>
<td><strong>2,968,500</strong></td>
<td><strong>4,123,200</strong></td>
<td><strong>5,458,000</strong></td>
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<table>
<thead>
<tr>
<th>NET POSITION</th>
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<tbody>
<tr>
<td></td>
<td>164,200</td>
<td>991,500</td>
<td>1,816,800</td>
<td>2,462,000</td>
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</tbody>
</table>

| CUMULATIVE NET REVENUE | $7,896,500.00 |

THE UNIVERSITY OF ARIZONA | UA Global
<table>
<thead>
<tr>
<th><strong>Comparison:</strong> Engineering Physics (Old) vs. Applied Physics (New)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BS in Engineering Physics (disestablished 2005?)</strong></td>
</tr>
<tr>
<td><strong>Target enrollees</strong></td>
</tr>
<tr>
<td><strong>Required physics courses</strong></td>
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<tr>
<td></td>
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<tr>
<td><strong>Required math courses</strong></td>
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<tr>
<td><strong>Required technical courses other than physics and math</strong></td>
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<tr>
<td><strong>Design capstone requirements</strong></td>
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<td></td>
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<tr>
<td><strong>Required non-technical courses</strong></td>
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<tr>
<td></td>
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<tr>
<td><strong>Preparation for grad school in physics</strong></td>
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<tr>
<td></td>
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<tr>
<td><strong>Summary of overall approach</strong></td>
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<tr>
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</tbody>
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