Physics at Maryland

TOM GLEASON

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DEPARTMENT OF PHYSICS, UNIVERSITY OF MARYLAND, COLLEGE PARK

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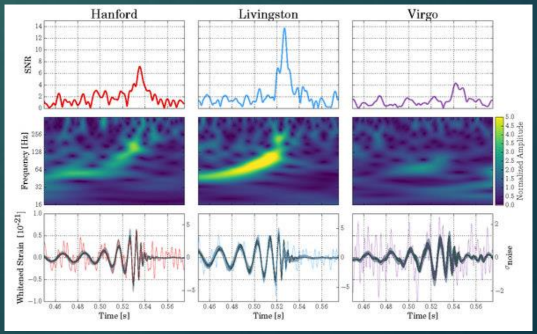
The Goal of Physics

- The goal of physics is to understand how everything in the universe works
- …We're not finished yet!

The Laser Interferometer Gravitational-Wave Observatory



Physics Contributions to Society

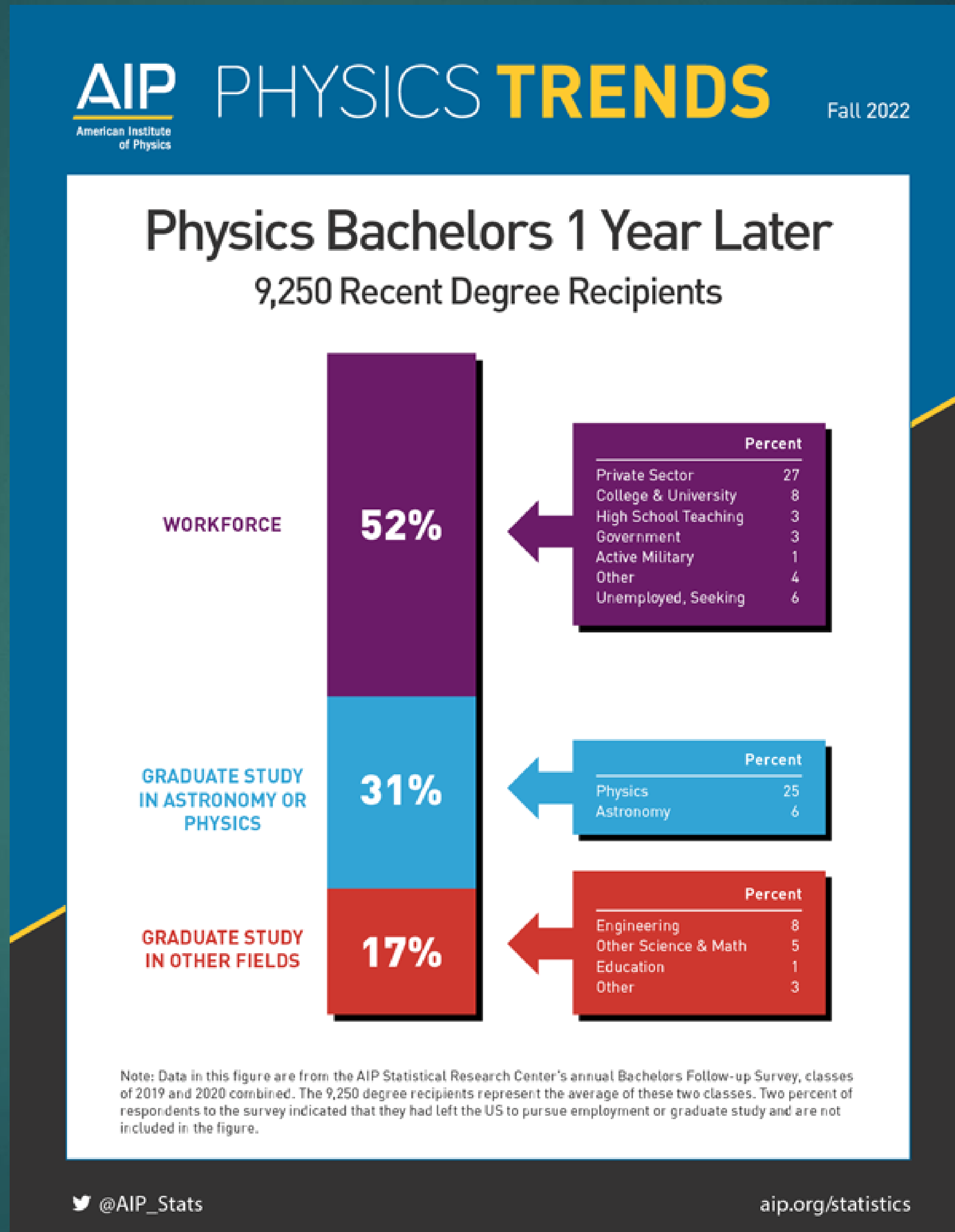
- Physics has advanced enormously in the past 100 years
  - Relativity
  - Quantum Mechanics
  - Nuclear
  - High energy
  - Astrophysics
- Physicists have also helped develop a lot of useful technology
  - Radar, GPS, transistors, the Internet, AI....

Robert Fischel – MA Physics
- Medical Device Inventor

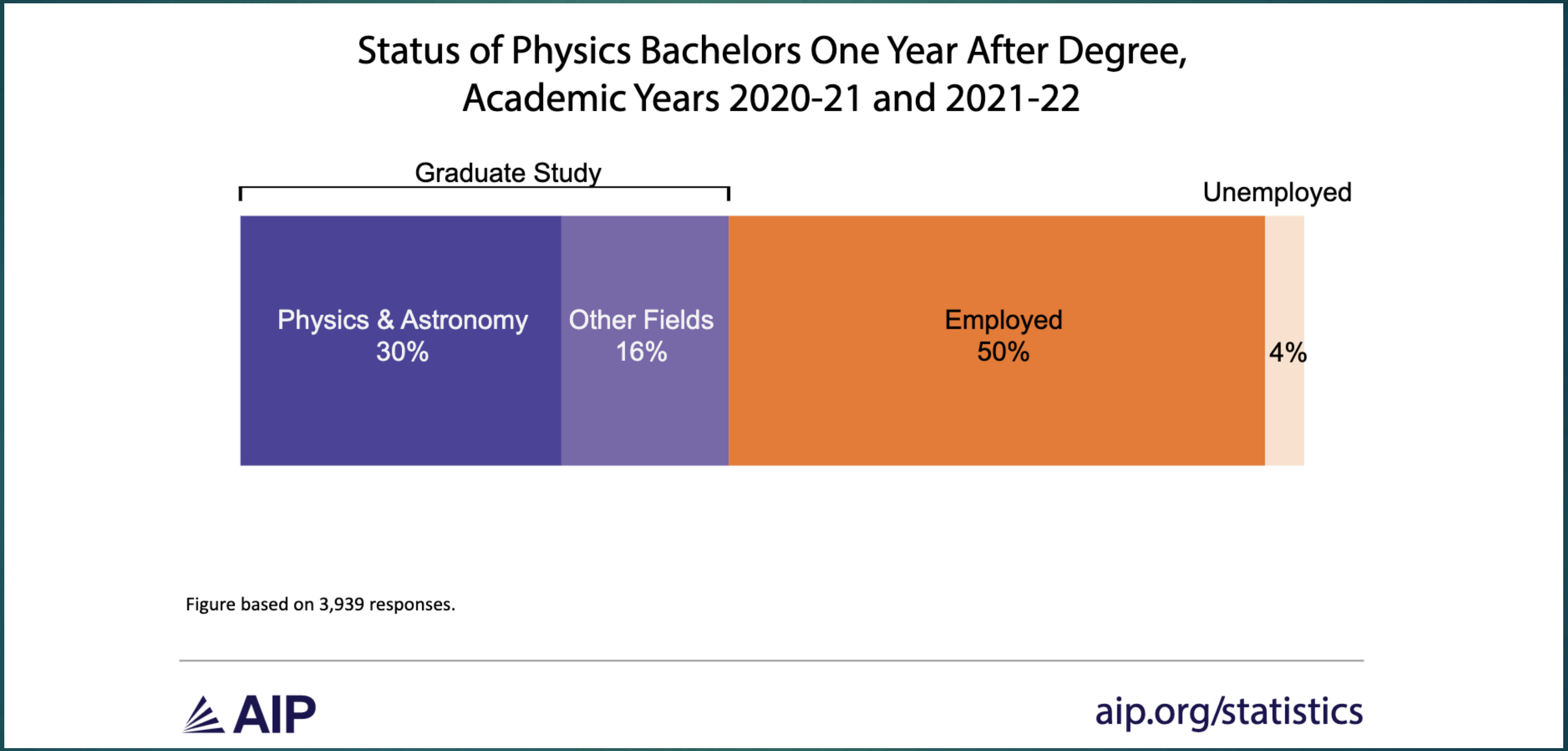
Why study physics?

- Gives a broad scientific background
  - Provides understanding of the foundations of science, engineering, and much of modern technology
- Teaches how to think and solve problems
  - Physicists analyze new physical situations based on fundamental concepts, laws of physics, and mathematics
  - They use experiments in the real world to decide whether a theory is correct
- Valuable to society
  - Often the first step to creating a new product or fixing an old problem

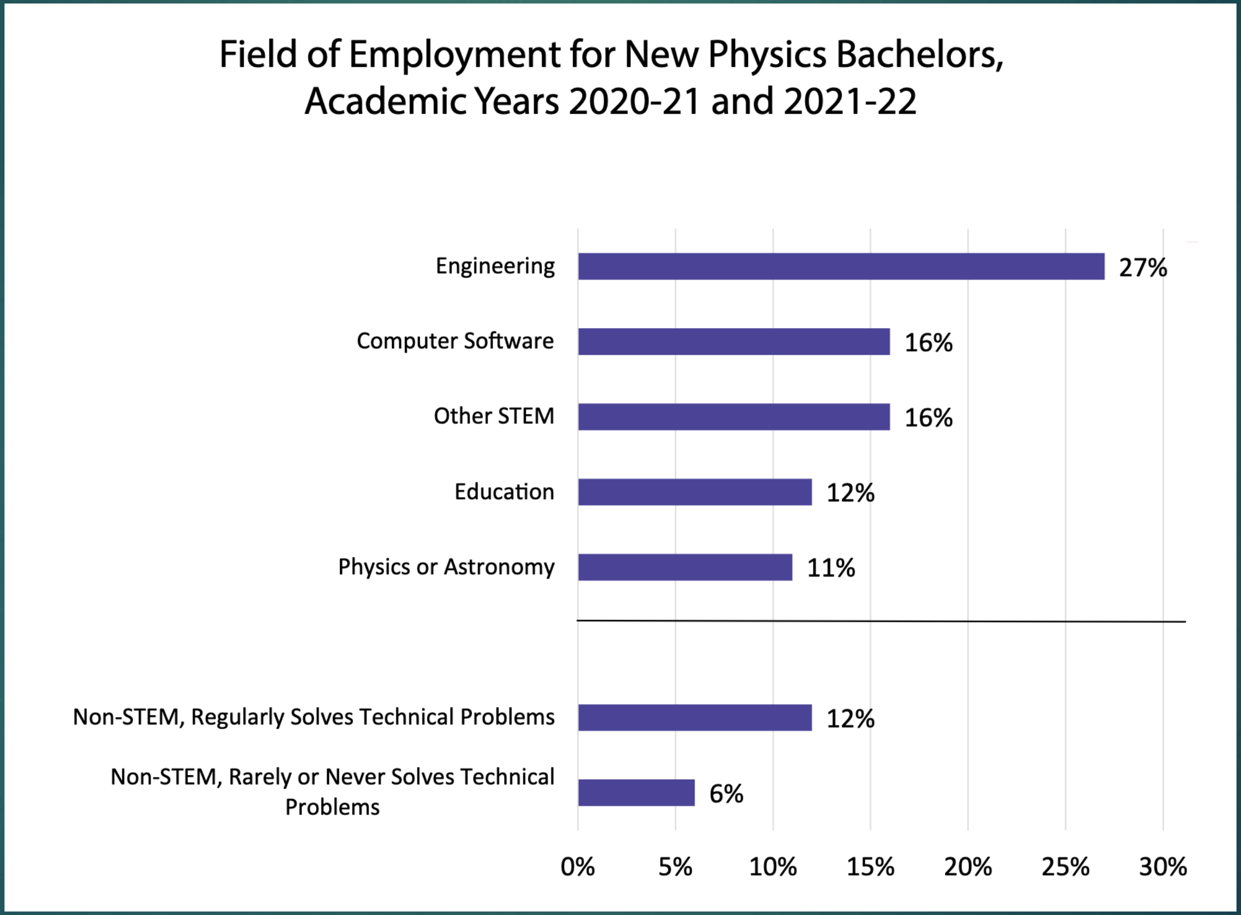
What do students do with a BS in Physics?



What do students do with a BS in Physics?



What do students do with a BS in Physics?



https://www.aip.org/statistics

Who hires students with a BS in Physics?

https://www.aip.org/statistics/whos-hiring-physics-bachelors

What can you do with a BS in Physics?

Employers Who Recently Hired Three or More New Physics Bachelors

Accenture
Accenture Federal Services
Actalent
Amazon
Amazon Web Services
Apple
Applied Materials
Applied Medical
Argonne National Laboratory
ASML
BAE Systems
Blue Origin
BNY Mellon
Boeing
Booz Allen Hamilton
Boston University
Bristol Myers Squibb
Brookhaven National Laboratory
CACI
California Institute of Technology
California Polytechnic State University
Capital One
Carnegie Mellon University
Citadel Securities
Citigroup
Cleveland Clinic
Collins Aerospace
Columbia University
Constellation Energy
Corning
Department of Defense
Epic Systems
General Dynamics Electric Boat
General Dynamics Mission Systems
General Motors
Genesis10
Georgia Tech Research Institute
Goldman Sachs
Google
Guided Discoveries
IBM
Infosys
Intel
IPG Photonics
Jane Street Capital
Johns Hopkins University
Johns Hopkins University Applied Physics Laboratory
JPMorgan Chase
KBR
L3Harris
Las Cumbres Observatory
Lawrence Berkeley National Laboratory
Leidos
Lockheed Martin
Los Alamos National Laboratory
Lowell Observatory
MACOM Technology Solutions
Maria Mitchell Observatory
Massachusetts General Hospital
Massachusetts Institute of Technology
Mathnasium
Mayo Clinic
McKinsey & Company
Medical University of South Carolina
Miami Cancer Institute
Micron
Microsoft
MIT Lincoln Laboratory
MITRE
National Institutes of Health
NAVAIR
Naval Nuclear Laboratory
Naval Oceanographic Office
Naval Sea Systems Command
Naval Surface Warfare Center, Dahlgren Division
Newgrange Design
North Carolina State University
Northern Arizona University
Northrop Grumman
Oak Ridge Associated Universities
Ohio State University
Open Systems International
Oracle
Peraton
PPD
Princeton University
Raytheon
SciTec
SLAC National Accelerator Laboratory
SRC Inc
Stanford University
State Farm
Stryker
Tesla
The Aerospace Corporation
U.S Air Force
U.S Army
U.S Marine Corps
U.S Navy
United States Patent & Trademark Office
United States Space Force
University of California, Los Angeles
University of Chicago
University of Iowa
University of Massachusetts, Amherst
University of Michigan
University of Minnesota
University of New Hampshire
University of Pennsylvania
University of Pittsburgh
University of San Diego
University of Washington
University of Wisconsin, Madison
Viavi Solutions
Wells Fargo
Wolfspeed
Yale University

This employer list comes from responses to AIP Research's Bachelor's Degree Recipient Follow-up Survey, Academic Years 2019-20 through 2023-24. This list is limited to employers who hired new physics bachelors into technical positions. The list does not include bachelors employed at elementary, middle, or high schools.

What can you do with a BS in Physics?

Naval Surface Warfare Center

US Nuclear Regulatory Commission

Northrop Grumman

US Patent & Trademark Office

Johns Hopkins Applied Physics Lab

Employers Who Recently Hired Three or More New Physics Bachelors

Accenture
Accenture Federal Services
Actalent
Amazon
Amazon Web Services
Apple
Applied Materials
Applied Medical
Argonne National Laboratory
ASML
BAE Systems
Blue Origin
BNY Mellon
Boeing
Booz Allen Hamilton
Boston University
Bristol Myers Squibb
Brookhaven National Laboratory
CACI
California Institute of Technology
California Polytechnic State University
Capital One
Carnegie Mellon University
Citadel Securities
Citigroup
Cleveland Clinic
Collins Aerospace
Columbia University
Constellation Energy
Corning
Department of Defense
Epic Systems
General Dynamics Electric Boat
General Dynamics Mission Systems
General Motors
Genesis10
Georgia Tech Research Institute
Goldman Sachs
Google
Guided Discoveries
IBM
Infosys
Intel
IPG Photonics
Jane Street Capital
Johns Hopkins University
Johns Hopkins University Applied Physics Laboratory
JPMorgan Chase
KBR
L3Harris
Las Cumbres Observatory
Lawrence Berkeley National Laboratory
Leidos
Lockheed Martin
Los Alamos National Laboratory
Lowell Observatory
MACOM Technology Solutions
Maria Mitchell Observatory
Massachusetts General Hospital
Massachusetts Institute of Technology
Mathnasium
Mayo Clinic
McKinsey & Company
Medical University of South Carolina
Miami Cancer Institute
Micron
Microsoft
MIT Lincoln Laboratory
MITRE
National Institutes of Health
NAVAIR
Naval Nuclear Laboratory
Naval Oceanographic Office
Naval Sea Systems Command
Naval Surface Warfare Center, Dahlgren Division
Newgrange Design
North Carolina State University
Northern Arizona University
Northrop Grumman
Oak Ridge Associated Universities
Ohio State University
Open Systems International
Oracle
Peraton
PPD
Princeton University
Raytheon
SciTec
SLAC National Accelerator Laboratory
SRC Inc
Stanford University
State Farm
Stryker
Tesla
The Aerospace Corporation
U.S Air Force
U.S Army
U.S Marine Corps
U.S Navy
United States Patent & Trademark Office
United States Space Force
University of California, Los Angeles
University of Chicago
University of Iowa
University of Massachusetts, Amherst
University of Michigan
University of Minnesota
University of New Hampshire
University of Pennsylvania
University of Pittsburgh
University of San Diego
University of Washington
University of Wisconsin, Madison
Viavi Solutions
Wells Fargo
Wolfspeed
Yale University

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AIP

aip.org/statistics

Unusual (?) Paths

Aaron B. (UMD alum) - double majored in math and graduate summa cum laude

- Decided not to go to graduate school to pursue his interest in cosmology
- Worked as an engineer at Johns Hopkins Applied Physics Lab
- Managed team of people with MS and PhD degrees
  - Had good communication skills
- Got interested in game theory
- Got a PhD in economics
- Spent some time in academia
- Is now a senior economist at Amazon

Why Study Physics at UMD?

- Large department with relatively small class size
  - ~320 majors
  - ~65 faculty (tenured/tenure-track)
  - Additional adjunct faculty from NIST and other Government agencies
- Separate introductory classes for physics majors
  - Relatively small class sizes
- Very strong department
  - 14th among all universities, 5th among public research universities (US News & World Report)
- We attract very talented students to our program
- We strongly encourage students to get involved in research with our faculty.

Physics Major Options at UMD

- The Physics Major (traditional program)
- Applied Physics Specialization
- Biophysics Specialization
- Physics Education Specialization

The Physics Major (Traditional)

Introductory Courses (17 credits)
PHYS170 (1): Professional Physics Seminar
PHYS171 (3): Introductory Physics: Mechanics
PHYS265 (3): Introduction to Scientific Programming
PHYS272 (3): Introductory Physics: Fields
PHYS275 (2): Experimental Physics I: Mechanics and Waves
PHYS273 (3): Introductory Physics: Oscillations and Waves
PHYS276 (2): Experimental Physics II: Electricity and Magnetism

Supporting Mathematics Courses (16 - 19 credits)
MATH140 (4): Calculus I
MATH141 (4): Calculus II
MATH241 (4): Calculus III

And one of the following options:

1) MATH243 (4): Introduction to Linear Algebra and Differential Equation, or
2) MATH240 (4): Introduction to Linear Algebra **and** MATH246 (3): Differential Equations for Scientists and Engineers

Upper-Level Courses (35 credits)
PHYS313 (4): Electricity and Magnetism I
PHYS371 (3): Modern Physics
PHYS375 (3): Experimental Physics III: Waves, Optics and Modern Physics
PHYS401 (4): Quantum Physics I
PHYS402 (3): Quantum Physics II
PHYS404 (3): Introduction to Statistical Thermodynamics
PHYS405 (3): Advanced Experiments lab
    Or PHYS407 (3): Undergraduate Experimental Research
PHYS410 (3): Classical Mechanics
PHYS413 (3): Electricity and Magnetism II
PHYS4XY (3): Advanced Physics Elective
PHYS4X'Y' (3): Advanced Physics Elective

Physics/Math AP Credit

Introductory Courses (17 credits)
PHYS170 (1): Professional Physics Seminar
PHYS171 (3): Introductory Physics: Mechanics
PHYS265 (3): Introduction to Scientific Programming
PHYS272 (3): Introductory Physics: Fields
PHYS275 (2): Experimental Physics I: Mechanics and Waves
PHYS273 (3): Introductory Physics: Oscillations and Waves
PHYS276 (2): Experimental Physics II: Electricity and Magnetism

Supporting Mathematics Courses (16 - 19 credits)
MATH140 (4): Calculus I
MATH141 (4): Calculus II
MATH241 (4): Calculus III

Calc AB 4 or 5 → MATH140

Calc BC 4 or 5 → MATH141
PHYS C Mechanics 4 or 5 → PHYS171

We encourage students to accept the AP credit and move on for the AP scores above.

PHYS C E&M 5 → PHYS272
We will accept a 5 on this exam for physics majors but encourage them to take PHYS272 and lose the AP credit.

Get Involved in Research at UMD

- AI and Physical Sciences
- Astro metrology
- Atomic, molecular & optical (6th)
- Biophysics
- Condensed matter (11th)
- Cosmic rays
- Elementary particles (13th)
- Gravity theory
- High energy
- Nonlinear dynamics
- Nuclear
- Particle astrophysics
- Physics education
- Plasma
- Quantum (6th)
- Quarks, hadrons, and nuclei

It's an opporunity!

Undergraduate Research at UMD

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Andrew Gilpin
Undergraduate Student
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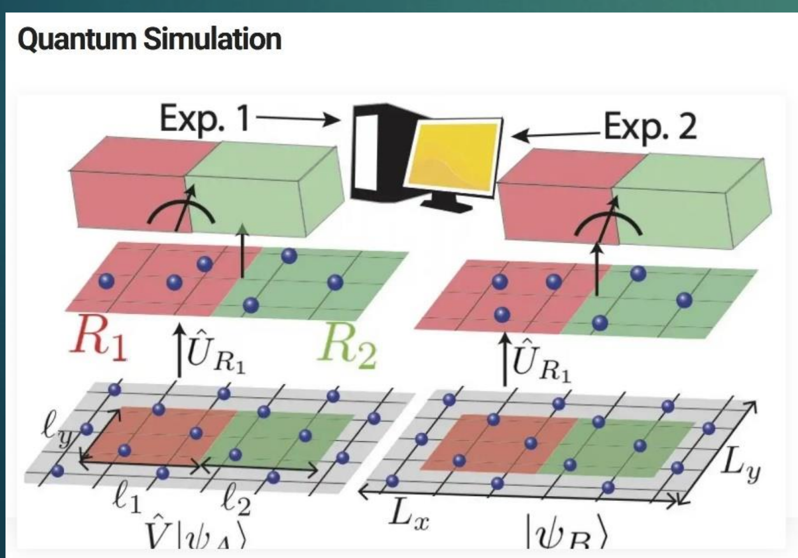
George Witt
Undergraduate Student
gwitt1@terpmail.umd.edu

Ronald Walsworth
Principal Investigator
Minta Martin Professor, University of Maryland
Founding Director, Quantum Technology Center (QTC)
Fellow, Joint Quantum Institute (JQI)

walsworth@umd.edu

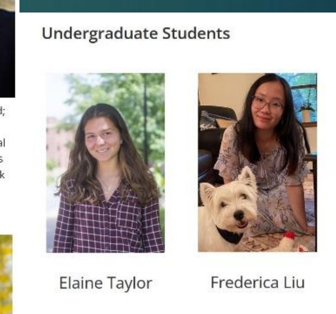
Google Scholar Citations



Quantum Simulation

Howard Milchberg, Principal Investigator

Howard Milchberg is jointly appointed to the departments of Physics and Electrical and Computer Engineering, and is affiliated with the Institute for Research in Electronics and Applied Physics. He received his B. Eng. in engineering physics from McMaster University (1979) and a Ph.D. in astrophysical sciences from Princeton University (1985). Professor Milchberg is the recipient of an NSERC Postgraduate Fellowship, National Research Council of Canada; NSF Presidential Young Investigator Award; and the APS John Dawson Award for Excellence in Plasma Physics Research. He is a fellow of the American Physical Society and the Optical Society of America. He is a UMD Distinguished Scholar-Teacher and was awarded the Senior Faculty Outstanding Research Award in UMD's Clark School of Engineering. Three of his graduate students have been recipients of APS-DPP's Marshall N. Rosenbluth Outstanding Doctoral Thesis Award.



Undergraduate Students

Elaine Taylor

Frederica Liu

Ela Rockafellow, Graduate Student

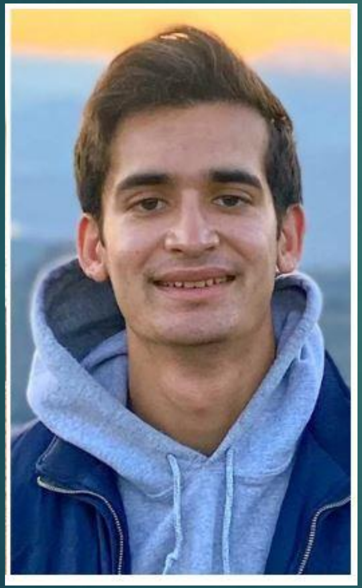
Ela joined our group in 2019 as an undergraduate before continuing as a graduate student. She earned a B.S. in Physics from University of Maryland in 2022, graduating magna cum laude, and received both the Goldwater Scholarship and NSF GRFP Fellowship for her undergraduate work with our mid-infrared lasers, including measuring ionization rates and simulating plasma induced frequency downshifting. As a graduate student, Ela is currently working on self-waveguiding laser wakefield acceleration. Outside of the lab, Ela rides horses competitively and enjoys drawing, painting, and backpacking.

Goldwater Scholars

STEM students need significant research experience to compete for national scholarships like the Goldwater.

Yash Anand and Malcolm Maas - 2024

Deven Bowman - 2023

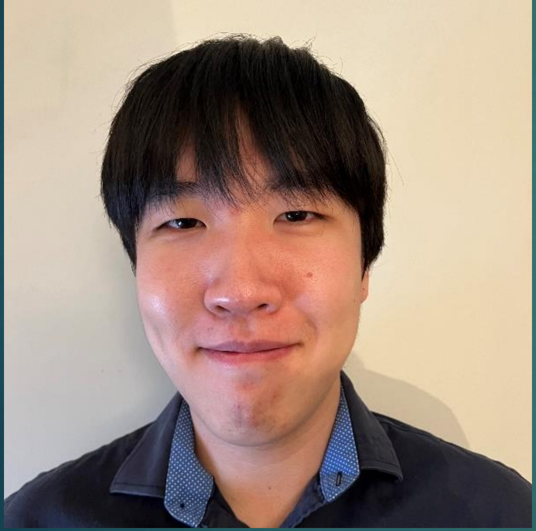


Goldwater Scholars

Ela Rockafellow - 2021

Patrick Kim – 2022

Scott Moroch - 2020



Goldwater Scholars

Colleges may nominate up to five candidates for the Goldwater Scholarship. UMD students, especially physics majors, are often strong candidates.

2019

John Martyn, Nick Poniatowski, Mark Zick

A student who took full advantage of UMD Physics Resources

Superconductivity, broken gauge symmetry, and the Higgs mechanism

Nicholas R. Poniatowski[a)]
Department of Physics, Center for Nanophysics and Advanced Materials, University of Maryland, College Park, Maryland 20742

(Received 11 September 2018; accepted 9 February 2019)

The association of broken symmetries with phase transitions is ubiquitous in condensed matter physics: crystals break translational symmetry, magnets break rotational symmetry, and superconductors break gauge symmetry. However, despite the frequency with which it is made, this last statement is a paradox. A gauge symmetry, in this case the U(1) gauge symmetry of electromagnetism, is a redundancy in our description of nature, so the notion of breaking such a "symmetry" is unphysical. Here, we will discuss how gauge symmetry breaks, and doesn't, inside a superconductor, and explore the fundamental relationship between gauge invariance and the striking phenomena observed in superconductors.
https://doi.org/10.1119/1.5093291

I. INTRODUCTION

If one spends enough time running in condensed matter circles, one will surely hear the off-handed remark that superconductors break gauge symmetry. On the other hand, our undergraduate electromagnetism class taught us that a gauge symmetry is a mere redundancy, not a physical symmetry that can reasonably be "broken" in a consistent theory. So, what does it actually mean for a gauge symmetry to "break," and why is this tied to superconductivity? In this article, we will address these questions, paying special attention to the role the mean field approximation plays in the study of superconductivity, and demonstrate how a classical field theory with spontaneously broken gauge symmetry can account for many of the spectacular properties of superconductors.

The first four sections include preliminary information, enabling a reader with only a basic familiarity with quantum mechanics to follow the remainder of the discussion. We review what precisely electromagnetic gauge symmetry is in Sec. II, the notion of spontaneously broken symmetries in Sec. III, and introduce second quantization and elements of quantum field theory in the context of superconductivity in Sec. IV. The reader familiar with this material is encouraged to skip ahead to the main discussion of spontaneous gauge symmetry breaking inside superconductors which comprises the remainder of the article. Specifically, we will discuss the constraints gauge invariance imposes on any effective description of the superconducting state following Refs. 1 and 2, and finally carefully consider the Anderson-Higgs mechanism which is the crux of the gauge-symmetry-breaking story.

II. ELECTROMAGNETIC GAUGE SYMMETRY

Let us review how gauge symmetry arises in classical electromagnetism,[3] starting with the Maxwell equations

$$\nabla \cdot \mathbf{E} = \rho, \tag{1}$$

$$\nabla \cdot \mathbf{B} = 0, \tag{2}$$

$$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0, \tag{3}$$

$$\nabla \times \mathbf{B} = \mathbf{j} + \frac{\partial \mathbf{E}}{\partial t}. \tag{4}$$

Here and throughout the remainder of the paper, we will use natural units where $\hbar = c = 1$, and further choose $\varepsilon_0 = \mu_0 = 1$. The second and third equations may be satisfied by writing the physical **E** and **B** fields in terms of the electromagnetic potentials

$$\mathbf{E} = -\nabla\varphi - \frac{\partial \mathbf{A}}{\partial t}, \tag{5}$$

$$\mathbf{B} = \nabla \times \mathbf{A}. \tag{6}$$

However, the choice of φ and **A** is not unique for a given configuration of **E** and **B**. Since $\nabla \times (\nabla\alpha) = 0$ for any scalar field $\alpha(\mathbf{x}, t)$, the transformation $\mathbf{A} \mapsto \mathbf{A} + \nabla\alpha$ leaves the magnetic field $\mathbf{B} = \nabla \times \mathbf{A}$ unchanged. To ensure the electric field is also invariant, we must simultaneously transform the scalar potential as $\varphi \mapsto \varphi - \partial_t \alpha$. This intrinsic ambiguity in the electromagnetic potentials is called *gauge symmetry*, and the transformation

$$\begin{aligned} \mathbf{A} &\mapsto \mathbf{A} + \nabla\alpha, \\ \varphi &\mapsto \varphi - \frac{\partial \alpha}{\partial t}, \end{aligned} \tag{7}$$

under which the electromagnetic field is invariant is called a *gauge transformation*. Since our choice of the gauge parameter α is arbitrary, all physical observables must be independent of α, that is, gauge invariant.

To incorporate quantum mechanics, recall that in the presence of an electromagnetic field the momentum of a particle with charge q must be shifted[4] $\mathbf{p} \mapsto \mathbf{p} - q\mathbf{A}$ which corresponds to the replacing the operator $-i\hbar\nabla \mapsto -i\hbar\nabla - q\mathbf{A}$ in quantum mechanics. The Schrödinger equation for such a charged particle in a potential $V(x)$ in the presence of an electromagnetic field is[5]

$$i\frac{\partial \psi}{\partial t} = -\frac{1}{2m}(\nabla - iq\mathbf{A})^2\psi + (V + q\varphi)\psi. \tag{8}$$

If we gauge transform the fields while *locally* rotating the phase of the wave function by the gauge parameter evaluated at each point in space and time

$$\psi(\mathbf{x}, t) \mapsto e^{iq\alpha(\mathbf{x},t)}\psi(\mathbf{x}, t), \tag{9}$$

The strange metal state of the electron-doped cuprates RL Greene, PR Mandal, NR Poniatowski, T Sarkar Annual Review of Condensed Matter Physics 11, 213-229	77	2020
Strange metallic magnetotransport in electron-doped cuprates N Poniatowski, T Sarkar, P Mandal Sarkar, R Greene Bulletin of the American Physical Society 65		2020
Superconductivity, broken gauge symmetry, and the Higgs mechanism NR Poniatowski American Journal of Physics 87 (6), 436-443	8	2019
Correlation between scale-invariant normal-state resistivity and superconductivity in an electron-doped cuprate T Sarkar, PR Mandal, NR Poniatowski, MK Chan, RL Greene Science Advances 5 (5), eaav6753	31	2019

2020 LeRoy Apker Award Recipient

Nicholas Poniatowski
University of Maryland, College Park

Citation:

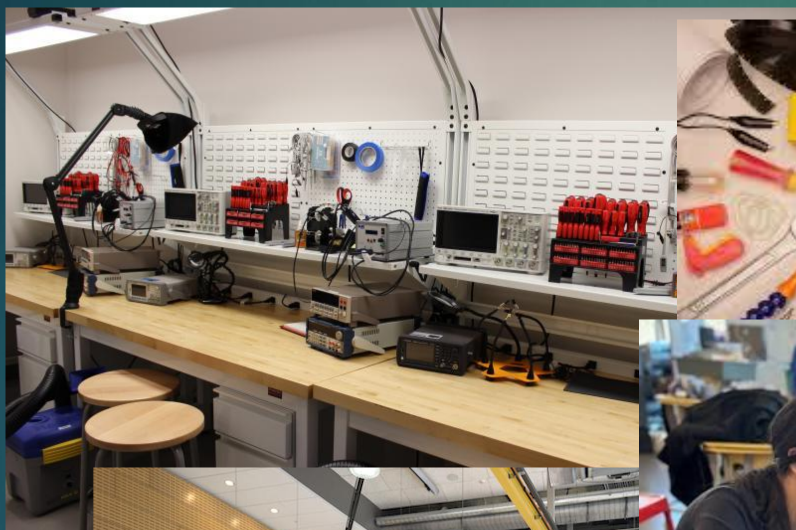
"For advancing our understanding of the transport properties of electron-doped high-temperature copper oxide superconductors through their synthesis, theoretical modeling and experimentation."

Background:

Nick Poniatowski graduated with a BS in physics from the University of Maryland, College Park in 2020. Throughout his time at the University of Maryland, he worked in Prof. Richard Greene's lab studying copper-oxide based high temperature superconductors. The nature of superconductivity in these materials has been a mystery for the past 30 years, despite being the subject of intense study. Nick's research focused on the non-superconducting state of these materials, a fascinating fundamental physics problem in its own right whose solution is believed to be a prerequisite to understanding high temperature

Other Campus Resources: Makerspaces

University of Maryland
Makerspace Initiative



FOSTERING A
CULTURE OF CREATIVITY.
DEMOCRATIZING ACCESS
TO RESOURCES.

TERRAPIN WORKS

Vortex – Physics Makerspace

Here is the presentation from yesterday, at the end is a sample proposal presentation. https://docs.google.com /…/1SG7JBhzMeNi_RNOW1ClcHnKwe-…/edit…

Jordan mentioned displaying the Fourier transform of sound at the last meeting, this is something we could definitely do at the next meeting, is anyone else interested?

It would involve piezoelectricity and fast Fourier transforms (really interesting algorithm)

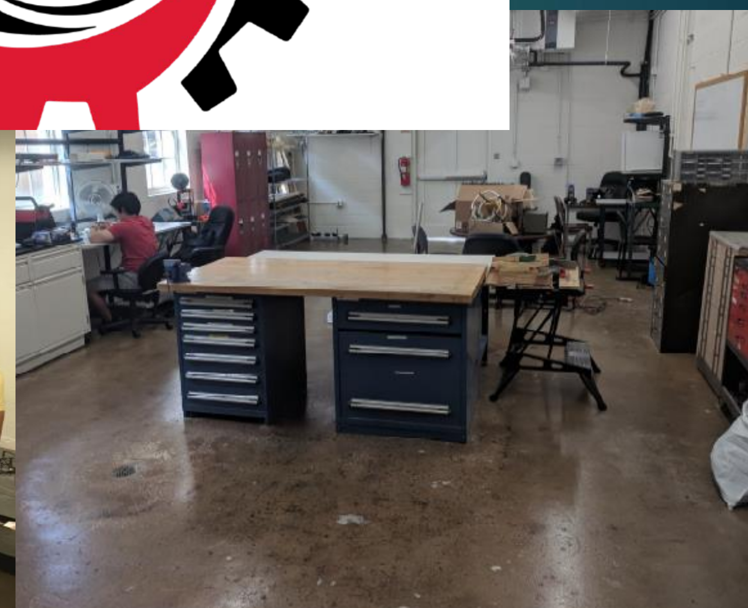
Makerspace I

Introduction to Ardu

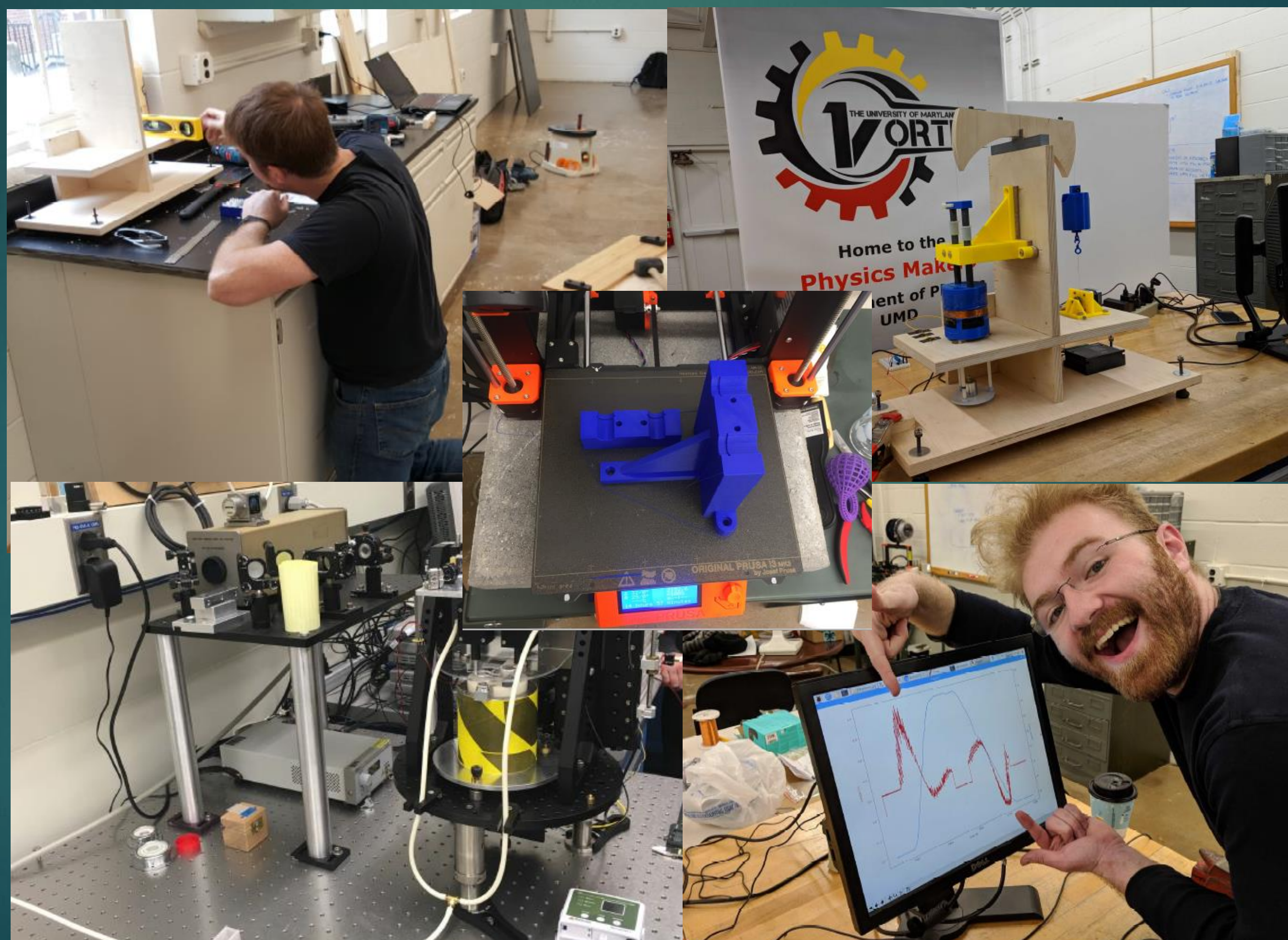
DOCS.GOOGLE.CO

THE UNIVERSITY OF MARYLAND PHYSICS

VORTEX



Vortex – Physics Makerspace



Admission to UG Physics at UMD

- The physics major at UMD is not a limited enrollment program.
- If a student is admitted to UMD, they can major in physics.
- If a student is deciding between engineering and physics, they should apply for admission to engineering.
- The engineering majors at UMD are limited enrollment programs.
- Engineering majors can take the physics major introductory sequence.

Admission to UG Physics at UMD

Fall Enrollment Beginning in Late August

Student Type	Early Action Deadline [1]	Early Action Decision Release	Regular Deadline [2]	Regular Decision Release	Enrollment Confirmation Deadline
U.S. and International Freshmen[3,4]	Nov. 1*	By Feb. 1	Jan. 20	By April 1	May 1
U.S. and International Transfer	March 1	By Late April	June 1	By Mid-July	30 days from date of admission
U.S. citizens applying to UMD at Shady Grove	June 1	Rolling basis	---	---	Before the beginning of the semester of admission
International students applying to UMD at Shady Grove	June 1	Rolling basis	---	---	Before the beginning of the semester of admission

https://admissions.umd.edu/apply/freshman-applicants

Studying Physics at Smaller Schools

- Juniata
- Small Faculty
- Worked for Bill Phillips
- REU Programs
- NIST SURF
- Other Government labs

Studying Physics at Smaller Schools

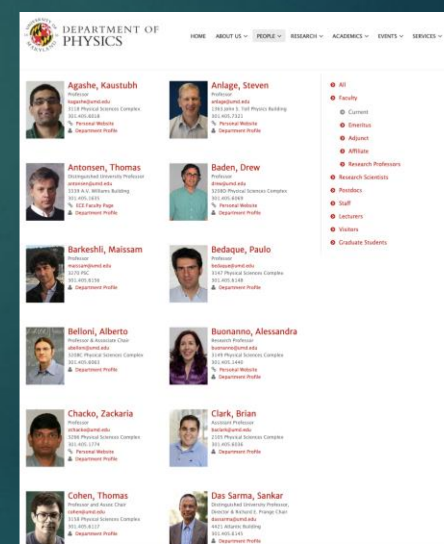
Small liberal arts schools with small faculties, like Juniata, may have fewer opportunities for undergraduate research. Students can pursue research opportunities through NSF REU Programs, NIST SURF Programs, contacting faculty at their local research university, etc.

It worked for Bill Phillips (Nobel price in physics, 1997)

NSF Research Experiences for Undergraduates

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

SUMMER UNDERGRADUATE RESEARCH FELLOWSHIP (SURF)



Questions? Comments?

Tom Gleason

tgleason@umd.edu

Thanks!

The Physics Major (Traditional)

Introductory Courses (17 credits)
PHYS170 (1): Professional Physics Seminar
PHYS171 (3): Introductory Physics: Mechanics
PHYS265 (3): Introduction to Scientific Programming
PHYS272 (3): Introductory Physics: Fields
PHYS275 (2): Experimental Physics I: Mechanics and Waves
PHYS273 (3): Introductory Physics: Oscillations and Waves
PHYS276 (2): Experimental Physics II: Electricity and Magnetism

Supporting Mathematics Courses (16 - 19 credits)
MATH140 (4): Calculus I
MATH141 (4): Calculus II
MATH241 (4): Calculus III

And one of the following options:

1) MATH243 (4): Introduction to Linear Algebra and Differential Equation, or
2) MATH240 (4): Introduction to Linear Algebra **and** MATH246 (3): Differential Equations for Scientists and Engineers

Upper-Level Courses (35 credits)
PHYS313 (4): Electricity and Magnetism I
PHYS371 (3): Modern Physics
PHYS375 (3): Experimental Physics III: Waves, Optics and Modern Physics
PHYS401 (4): Quantum Physics I
PHYS402 (3): Quantum Physics II
PHYS404 (3): Introduction to Statistical Thermodynamics
PHYS405 (3): Advanced Experiments lab
    Or PHYS407 (3): Undergraduate Experimental Research
PHYS410 (3): Classical Mechanics
PHYS413 (3): Electricity and Magnetism II
PHYS4XY (3): Advanced Physics Elective
PHYS4X'Y' (3): Advanced Physics Elective

The Physics Major

Sample schedule. Actual Schedules will vary.

Fall	Credits	Spring	Credits
MATH140	4	MATH141	4
PHYS170	1	PHYS171/275	5
Elective/ Gen Ed	3	Electives/ Ged Ed	3
Elective/Gen Ed	3	Elective/Ged Ed	3
Elective/ ENGL101 (FSAW)	3		
Total	14	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
MATH241	4	MATH243	4
PHYS272	3	PHYS273/276	5
PHYS265	3	Elective/Gen Ed	3
Electives/Ged Ed	3	Elective/Gen Ed	3
Elective/Gen Ed	3		
Total	15	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
PHYS313	4	PHYS401	4
PHYS371	3	PHYS413	3
PHYS375	3	Elective/GenEd	3
Gen Ed	3	Elective/Gen Ed	3
Elective/Gen Ed	3	Elective	2
Total	16	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
PHYS402	3	PHYS405	3
PHYS404	3	PHYS410	3
PHYS4XY	3	PHYS4X'Y'	3
Elective/Gen Ed	6	Elective/Gen Ed	6
Total	15	**Total**	15

The Physics Major - Applied Physics Specialization

Introductory Courses (19 credits)
PHYS170 (1): Professional Physics Seminar
PHYS171 (3): Introductory Physics: Mechanics
PHYS265 (3): Introduction to Scientific Programming
PHYS272 (3): Introductory Physics: Fields
PHYS275 (2): Experimental Physics I: Mechanics and Waves
PHYS273 (3): Introductory Physics: Oscillations and Waves
PHYS276 (2): Experimental Physics II: Electricity and Magnetism
ENME272 (2): Introduction to Computer Aided Design

Supporting Mathematics Courses (16 - 19 credits)
MATH140 (4): Calculus I
MATH141 (4): Calculus II
MATH241 (4): Calculus III
One of the following options (4 - 7):

1) MATH243 (4): Introduction to Linear Algebra and Differential Equation, or
2) MATH240 (4): Introduction to Linear Algebra **and** MATH246 (3): Differential Equations for Scientists and Engineers

Upper-Level Courses (32 credits)
PHYS313 (4): Electricity and Magnetism I
PHYS371 (3): Modern Physics
PHYS375 (3): Experimental Physics III: Waves, Optics and Modern Physics
PHYS401 (4): Quantum Physics I
PHYS404 (3): Introduction to Statistical Thermodynamics
PHYS413 (3): Electricity and Magnetism II
PHYS456 (3): Making Physics Experiments
PHYS474 (3): Computational Physics
PHYS4XY (3): Advanced Physics Elective
One of the following:

PHYS485 (3): Electronic Circuits
PHYS487 (3): Computerized Instrumentation

The Physics Major - Applied Physics Specialization

Sample schedule. Actual Schedules will vary.

Fall	**Credits**	**Spring**	**Credits**
MATH140	4	MATH141	4
PHYS170	1	PHYS171/275	5
ENGL101	3	ENME272	2
Gen Ed	3	Gen Ed	3
Elective	4	Elective	1
Total	15	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
MATH241	4	MATH243	4
PHYS272	3	PHYS273/276	5
PHYS265	3	Gen Ed/Elective	3
Elective	5	Elective/Gen Ed	3
Total	15	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
PHYS313	4	PHYS401	4
PHYS371	3	PHYS413	3
PHYS375	3	PHYS456	3
Elective/Gen Ed	3	Elective/Gen Ed	3
Elective	2	Elective	2
Total	15	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
PHYS404	3	PHYS3474	3
PHYS485	3	PHYS4XY	3
Gen Ed	3	Gen Ed	3
Electives	6	Electives	6
Total	15	**Total**	15

The Physics Major - Biophysics Specialization

Introductory Courses (37 credits)
PHYS170 (1): Professional Physics Seminar
PHYS171 (3): Introductory Physics: Mechanics
PHYS265 (3): Introduction to Scientific Programming
PHYS272 (3): Introductory Physics: Fields
PHYS275 (2): Experimental Physics I: Mechanics and Waves
PHYS273 (3): Introductory Physics: Oscillations and Waves
PHYS276 (2): Experimental Physics II: Electricity and Magnetism
BSCI170 (3): Principles of Molecular & Cellular Biology
BSCI171 (1): Principles of Molecular & Cellular Biology Laboratory
CHEM131 (3): Chemistry I - Fundamentals of General Chemistry
CHEM132 (1): General Chemistry I Laboratory
CHEM231 (3): Organic Chemistry I
CHEM232 (1): Organic Chemistry Laboratory I
CHEM241 (3): Organic Chemistry II
CHEM242 (1): Organic Chemistry Laboratory II
CHEM271 (2): General Chemistry and Energetics
CHEM272 (2): General Bioanalytical Chemistry Laboratory

Supporting Mathematics Courses (16 - 19 credits)
MATH140 (4): Calculus I
MATH141 (4): Calculus II
MATH241 (4): Calculus III
And one of the following options:

1) MATH243 (4): Introduction to Linear Algebra and Differential Equation, or
2) MATH240 (4): Introduction to Linear Algebra **and** MATH246 (3): Differential Equations for Scientists and Engineers

Upper-Level Courses (26 - 27 credits)
BSCI330 (4): Cell Biology and Physiology
BCHM461 (3): Biochemistry I
PHYS313 (4): Electricity and Magnetism I
PHYS371 (3): Modern Physics
PHYS404 (3): Introduction to Statistical Thermodynamics
PHYS483 (3): Biophysics
PHYS4XY (3): Advanced Physics Elective
One of the following:
PHYS375 (3): Experimental Physics III: Waves, Optics and Modern Physics
BSCI4XY (3-4): An Approved Advanced BSCI Elective

Note: Students interested in medical school should consult a pre-med advisor (prehealth.umd.edu) for additional course recommendations.

The Physics Major - Biophysics Specialization

Sample schedule. Actual Schedules will vary.

Fall	Credits	Spring	Credits
MATH140	4	MATH141	4
PHYS170	1	PHYS171/275	5
ENGL101	3	CHEM131/132	4
BSCI170/171	4	Gen Ed	3
Gen Ed	3		
Total	15	**Total**	16
Fall	**Cr.**	**Spring**	**Cr.**
MATH241	4	MATH243	4
PHYS272	3	PHYS273/276	5
CHEM231/232	4	CHEM241/242	4
PHYS265	3	Elective/Gen Ed	3
Total	14	**Total**	16
Fall	**Cr.**	**Spring**	**Cr.**
PHYS313	4	PHYS371	3
CHEM271/272	4	BSCI330	4
Gen Ed	3	BCHM461	3
Elective/Gen Ed	3	Elective/Gen Ed	3
		Elective	2
Total	14	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
PHYS404	3	PHYS375 or BSCI4XY	3
PHYS483	3	PHYS4XY	3
Gen Ed	3	Gen Ed	3
Electives	6	Electives	6
Total	15	**Total**	15

The Physics Major – Education Specialization

The Education Physics area of concentration is designed to accommodate students obtaining a teaching certificate through the College of Education. **However, completing all the courses in the Education Physics area of concentration does not in itself satisfy all requirements for obtaining a teaching certificate.** Students pursuing the Education Physics area of concentration who want to also obtain a teaching certificate in secondary education must first apply and be admitted to the Secondary Education Program in the College of Education and then complete additional courses in that program.

Introductory Courses (20 credits)
PHYS170 (1): Professional Physics Seminar
PHYS171 (3): Introductory Physics: Mechanics
PHYS265 (3): Introduction to Scientific Programming
PHYS272 (3): Introductory Physics: Fields
PHYS275 (2): Experimental Physics I: Mechanics and Waves
PHYS273 (3): Introductory Physics: Oscillations and Waves
PHYS276 (2): Experimental Physics II: Electricity and Magnetism
TLPL101 (1): Inquiry Teaching of STEM in Elementary School
TLPL102 (2): Inquiry Teaching of STEM in Middle School

Supporting Mathematics Courses (16 - 19 credits)
MATH140 (4): Calculus I
MATH141 (4): Calculus II
MATH241 (4): Calculus III
And one of the following options:

1) MATH243 (4): Introduction to Linear Algebra and Differential Equation, or
2) MATH240 (4): Introduction to Linear Algebra **and** MATH246 (3): Differential Equations for Scientists and Engineers

Upper-Level Requirements (28 - 29 credits)
EDHD426 (3): Cognitive and Motivational Literacy Content
TLPL401 (3): Student-Centered Curriculum Instruction
TLPL414 (3): Knowing and Learning in Mathematics and Science
TLPL415 (3): Perspectives in Science
PHYS371 (3): Modern Physics
PHYS313 (4): Electrostatics
PHYS375 (3): Experimental Physics III: Waves, Optics and Modern Physics*
PHYS4XY (3): Advanced Physics Elective
One of the following (3-4):

- PHYS401 (4): Quantum Physics I
- PHYS404 (3): Introduction to Statistical Thermodynamics
- PHYS410 (3): Classical Mechanics
- PHYS413 (3): Electricity and Magnetism II

*PHYS375 may be replaced by an additional, non-seminar, 400-level approved Physics course of 3-4 credits not being used to satisfy another requirement.

The Physics Major - Education Specialization

Sample schedule. Actual Schedules will vary.

Fall	Credits	Spring	Credits
MATH140	4	MATH141	4
PHYS170	1	PHYS171/275	5
TLPL101	1	TLPL102	2
ENGL101	3	Elective/Ged Ed	3
Electives/Gen Eds	6	Elective	1
Total	15	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
MATH241	4	MATH243	4
PHYS272	3	PHYS273/276	5
PHYS265	3	Elective/Gen Ed	3
TLPL401	3	Elective/Gen Ed	3
Elective/Gen Ed	3		
Total	16	**Total**	15
Fall	**Cr.**	**Spring**	**Cr.**
PHYS313	4	PHYS375	3
PHYS371	3	TLPL415	3
TLPL414	3	Elective/GenEd	3
Gen Ed	3	Elective/Gen Ed	3
Elective/Gen Ed	3	Elective	2
Total	16	**Total**	14
Fall	**Cr.**	**Spring**	**Cr.**
EDHD426	3	PHYS4XY	3
PHYS401/404/410 or 413	3-4	Electives	12
Elective	3		
Elective/Gen Ed	4-5		
Total	14	**Total**	15

John S. Toll - The Department Builder (1950s-60s)

Became chair at age 29 (1953)

Recruited dozens of top scientists from around the world

Created collaborative culture - daily afternoon tea tradition

Vision: *"An outstanding research professor is not just twice as valuable as an average college teacher; he or she is often 20 to 40 times more valuable."*

Legacy: Physics building named in his honor (2001)

Pioneering Discoveries (1960s-1980s)

Three Revolutionary Contributors

Joseph Weber

Oscar Greenberg

Charles Misner

Joseph Weber (1919 – 2000)

Innovation: Built first gravitational wave detectors (Weber bars) in 1960s

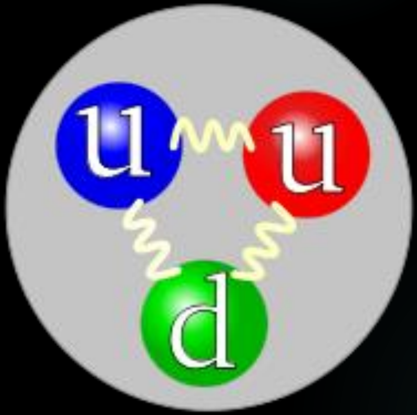
Controversy: Claimed detection in 1969 - not reproduced by others

Vindication: *"If Weber were alive today, he would share the Nobel Prize"* - UMD colleague Ho Jung Paik

Legacy: One of his detectors now displayed at LIGO facility in Hanford, Washington

Impact: Opened field that led to 2015 LIGO discoveries

Oscar W. Greenberg (1932 – present)



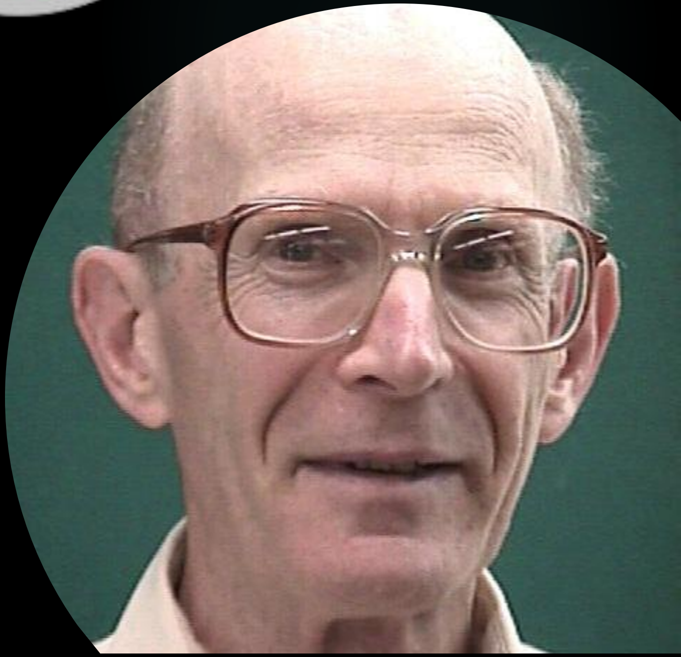
Breakthrough: Introduced "color charge" concept for quarks (1964)

Problem Solved: Resolved spin-statistics paradox in quark theory

Recognition: Robert Oppenheimer's reaction: "*Greenberg, it's beautiful!*"

Impact: Color charge became fundamental to Standard Model

Legacy: Enabled theory of strong nuclear force (QCD)



Charles Misner (1932 – 2023)

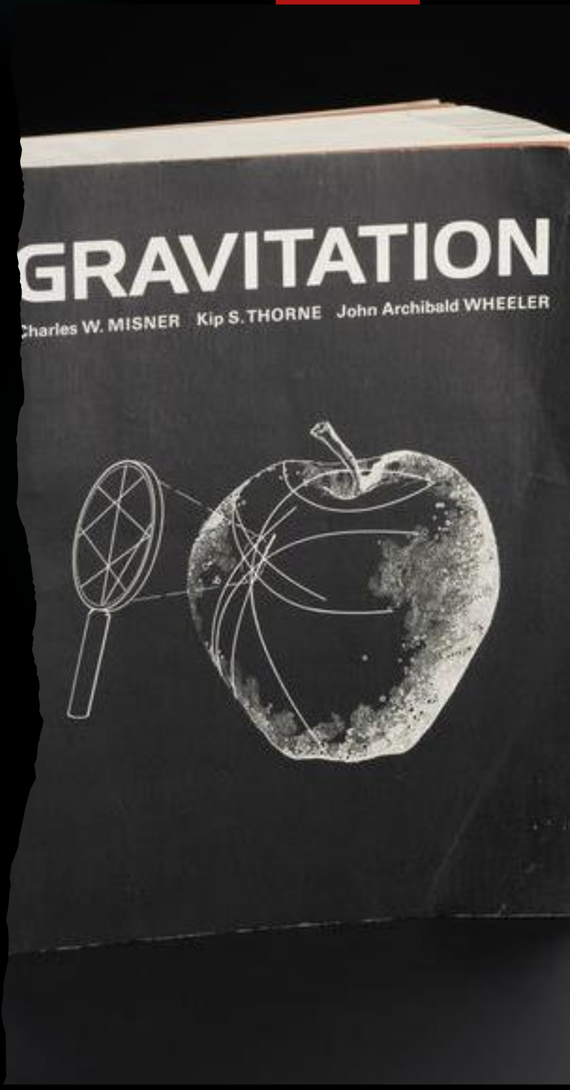
Classic Text: Co-authored "*Gravitation*" (1973) with John A. Wheeler & Kip Thorne

Mathematical Innovation: Developed ADM formalism (Einstein Medal 2015)

Mentorship: Advised 23 doctoral students, many now leading physicists

One student: Richard Isaacson → NSF program officer → supported LIGO funding

Enduring Impact: "*Gravitation*" still used worldwide today



Modern Excellence in Physics

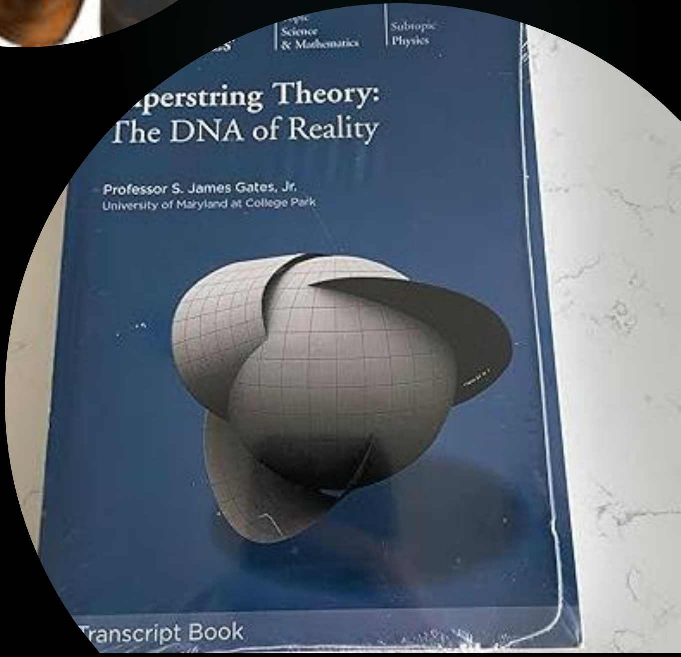
Continuing the Legacy of Innovation

S. James Gates Jr. - Supersymmetry Trailblazer

Ellen Williams - Nanotechnology Leader

Expanding excellence across new frontiers

S. James Gates, Jr. (1950 – present)



Historic First: First African-American theoretical physicist in National Academy of Sciences (2013)

Academic Pioneer: First MIT Ph.D. in supersymmetry (1977)

Foundational Work: Co-authored first comprehensive supersymmetry textbook (1984)

National Service: President Obama's science council, National Medal of Science

UMD Return: Now John S. Toll Professor of Physics (2022)

Ellen Williams (1953 – present)

Trailblazer: One of first female full professors in UMD physics

Institution Builder: Founded Materials Research Science & Engineering Center (1996)

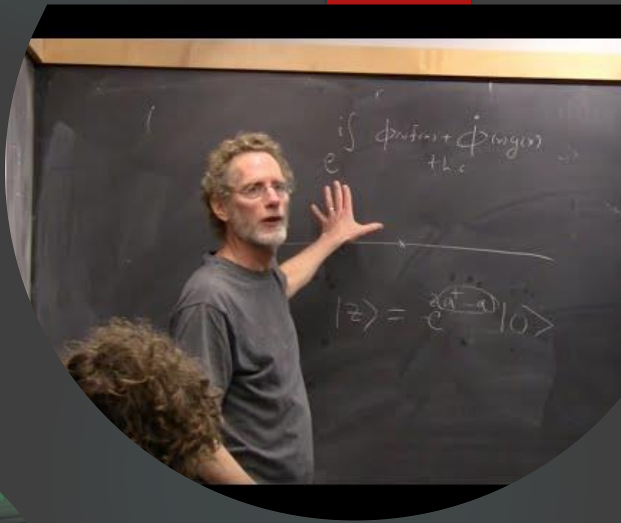
National Impact: ARPA-E Director (2014-2017), advancing clean energy

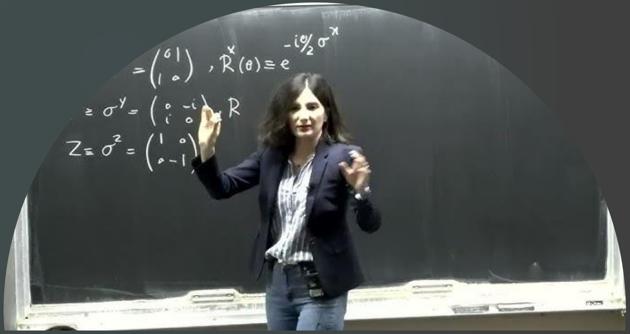
Research Excellence: Pioneered scanning tunneling microscopy at atomic level

Recognition: National Academy of Sciences, Royal Society of London

Current Highlights in Physics at UMD

- Joint Quantum Institute (collaboration with NIST)
- Biophysics
- Particle Astrophysics
- Nuclear Physics Theory
- Black Holes
- Atomic, Molecular, and Optical Physics (AMO)





Current Highlights in Physics at UMD

- **Condensed Matter Physics**
- **Quantum Materials Center, Superconductivity**
- **Light Interferometer Gravitational-Wave Observatory (LIGO)**
- **Quantum Steampunk, Thermodynamics**
- **High Energy Physics**
- **Elementary Particle Theory**

One of the Largest Physics Departments in the US

- 65 Tenure/Tenure Track Faculty
- 49 Adjunct Faculty
- (Staff Scientist from NIST, NIH, NASA, and other National labs.)
- Over 30 Areas of Physics Research