Creating Rewarding Careers in Industrial Physics and Physics Education

UCSD
Physics Colloquium

February 15, 2024

Dr. Larry Woolf
Technical Fellow
General Atomics Aeronautical Systems, Inc.
www.ga-asi.com
President/Chair
General Atomics Sciences Education Foundation
www.sci-ed-ga.org

SCIENCES EDUCATION FOUNDATION
GENERAL ATOMICS

Outline

- Part 1: Career in industry
- Part 2: Education path
- Part 3: APS involvement

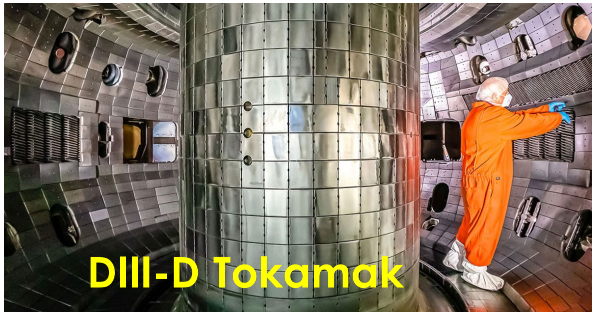
Limited highlights reel – range, fun

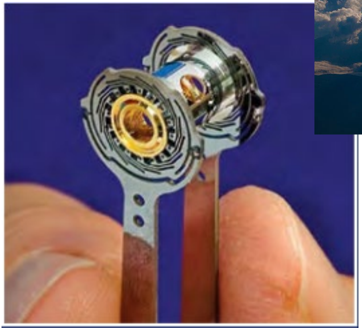
- What does an industrial physicist do?
- Can you get involved in physics education in industry?
- What is the best way to prepare undergraduate physics students for careers?
- How can APS play a major role in your professional life?
- How are these questions related?

Part 1: My technical career in 4 snapshots

- **PhD UCSD, "Low temperature heat capacity of magnetic superconductors," Prof. Brian Maple 1980**
- **Post-doc at Exxon Research, 1980-1982**
- **Hired as solid state physicist at General Atomics (GA) in 1982 to help develop non-nuclear programs.**
- **At GA, GA-ASI for 41 years – mostly materials R&D**

Every story and perspective of life in industry is unique and changes depending on the stage of one's career





NIF Ignition Target

GENERAL ATOMICS

Investigate 2-D Structures: Graphite Fibers

Used graduate school knowledge to set up low temperature high H lab to measure magnetoresistance →

https://www.sho.espci.fr/spip.php?article48&lang=fr

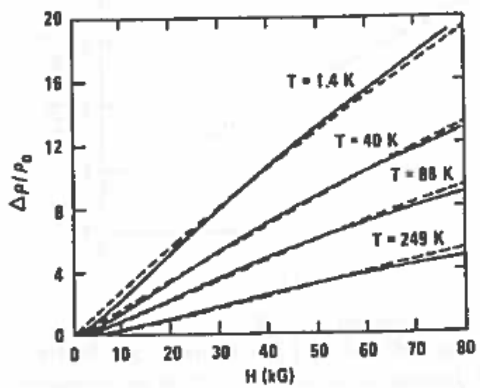
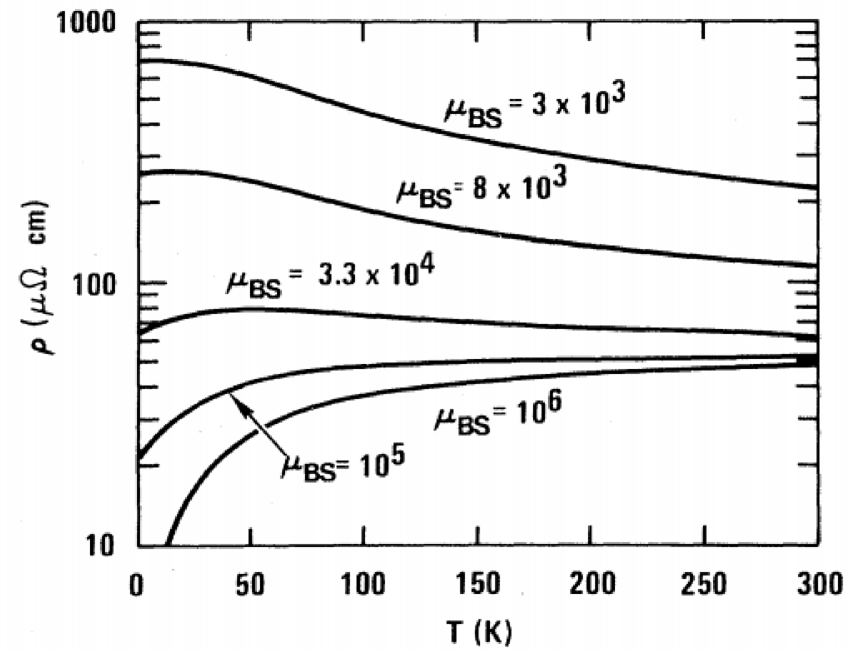


FIG. 1. Magnetoresistance vs magnetic field H for a BDF at a variety of temperatures (dashed curve). Also shown are fits to the data using Eq. (17) (solid line).



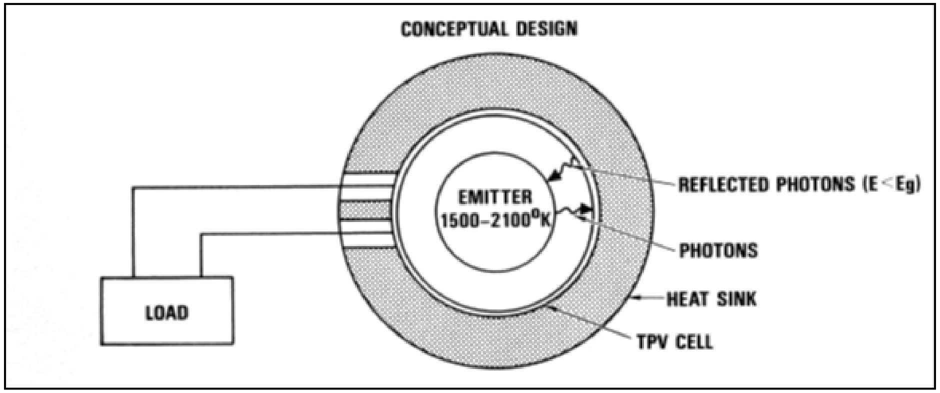
PHYSICAL REVIEW B VOLUME 30, NUMBER 2 15 JULY 1984

Electrical transport properties of benzene-derived graphite fibers

L. D. Woolf, J. Chin, Y. R. Lin-Liu, and H. Ikezi
GA Technologies, Inc., P.O. Box 85608, San Diego, California 92138
(Received 28 December 1983)

Model thermophotovoltaic (TPV) energy conversion systems and test cells – space nuclear power

High temperature materials + optical properties →



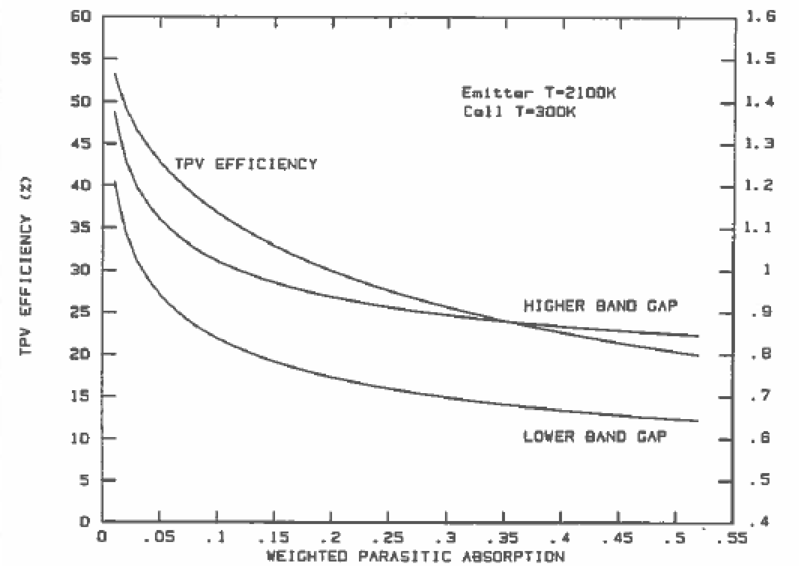


Fig. 9. Optimum TPV efficiency and associated lower and higher bandgaps *vs.* weighted parasitic absorption $\bar{A}_{par}$ for an emitter temperature of 2100 K and cell temperature of 300 K.

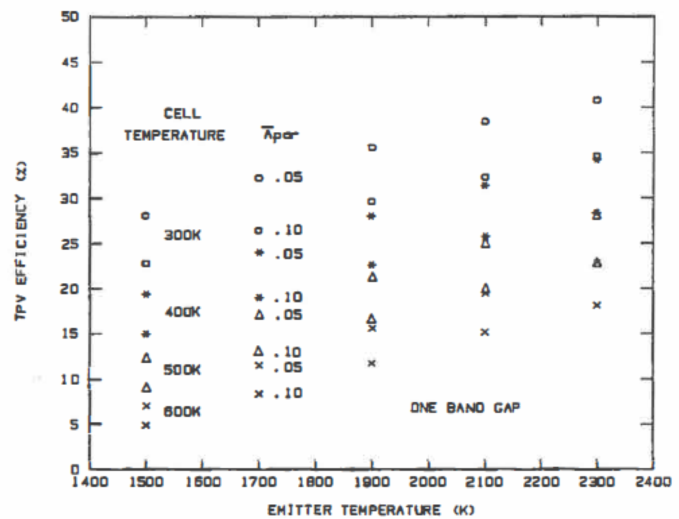


Fig. 1. Maximum TPV efficiency of a single bandgap cell as a function of emitter temperature for selected values of cell temperature and weighted parasitic absorption $\bar{A}_{par}$.

Solar Cells, *19* (1986 - 1987) 19 - 38 19

OPTIMUM EFFICIENCY OF SINGLE AND MULTIPLE BANDGAP CELLS IN THERMOPHOTOVOLTAIC ENERGY CONVERSION

L. D. WOOLF

GA Technologies Inc., P.O. Box 85608, San Diego, CA 92138 (U.S.A.)

(Received October 3, 1985; accepted in revised form December 23, 1985)

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HTS discovered: Led high temperature superconducting (HTS) wire development project

Graduate school + ceramic materials + thick film coatings →

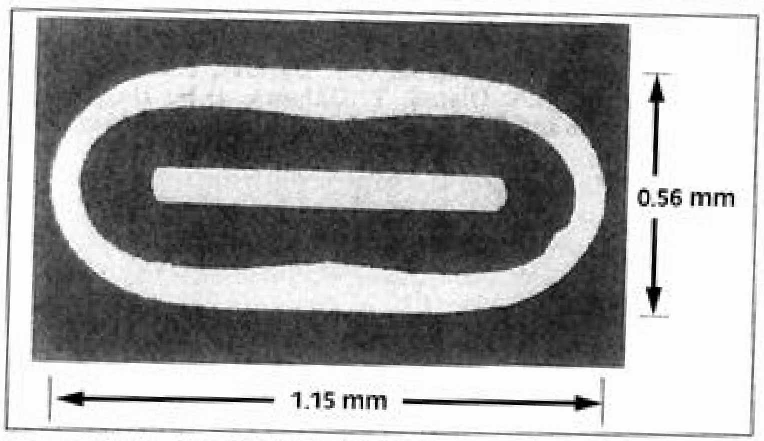


Fig. 4. Polished transverse cross section of an as-coated silver and superconductor coated silver tape.

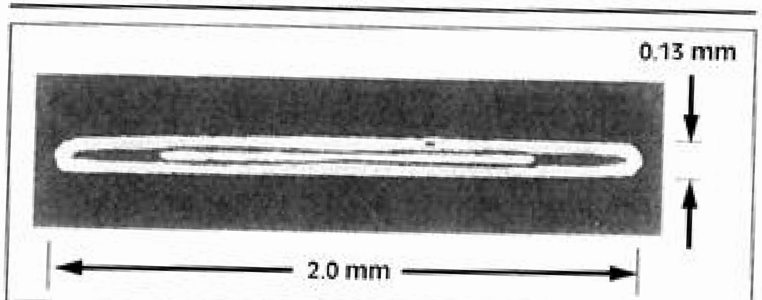


Fig. 5. Polished transverse cross section of a fully processed silver and superconductor coated silver tape.

- 7 years, papers, patents, presentations
- Effort was commercially unsuccessful
- Motivated education activities

Journal of Electronic Materials, Vol. 24, No. 12, 1995

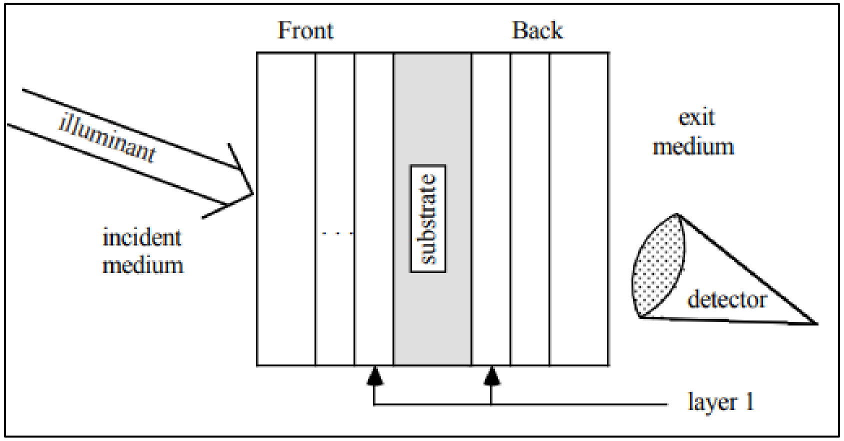
Special Issue Paper

Fabrication of Long Length Bi-2223 Superconductor Tape Using Continuous Electrophoretic Deposition on Round and Flat Substrates

L.D. WOOLF, T.L. FIGUEROA, R.A. OLSTAD, F.E. ELSNER, and T. OHKAWA

Pacific Superconductors Division, General Atomics, San Diego, CA 92186

Thin film coatings



https://sspectra.com/files/win_demo/manual.pdf

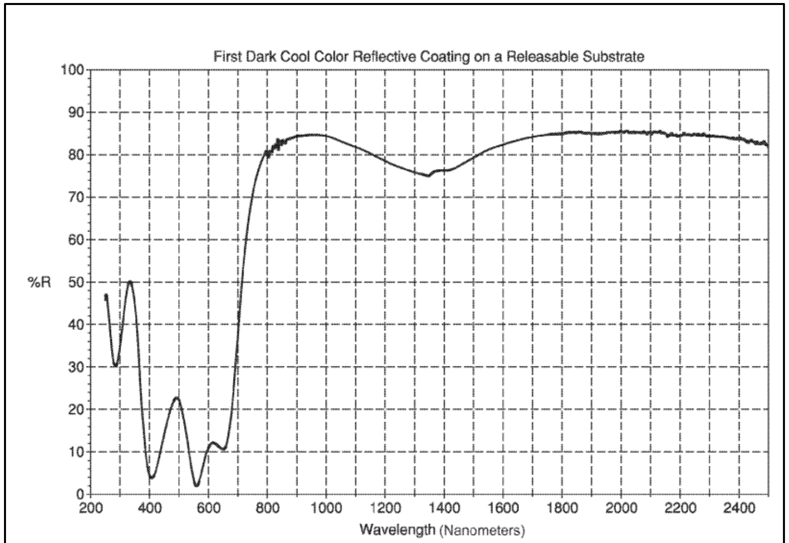
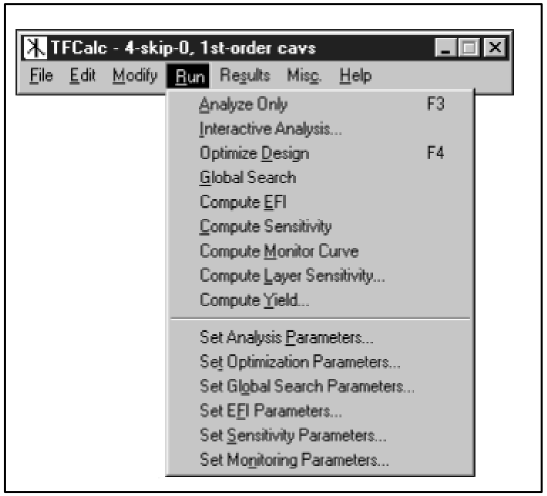


FIG. 10

Self taught: thin film coating design, development, fabrication, testing → (2001-present)



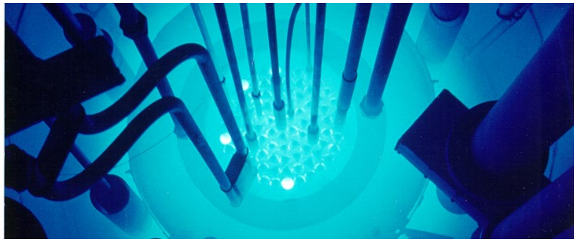
(12) **United States Patent** (10) **Patent No.: US 8,932,724 B2**
Woolf (45) **Date of Patent: Jan. 13, 2015**

(54) **REFLECTIVE COATING, PIGMENT, COLORED COMPOSITION, AND PROCESS OF PRODUCING A REFLECTIVE PIGMENT**

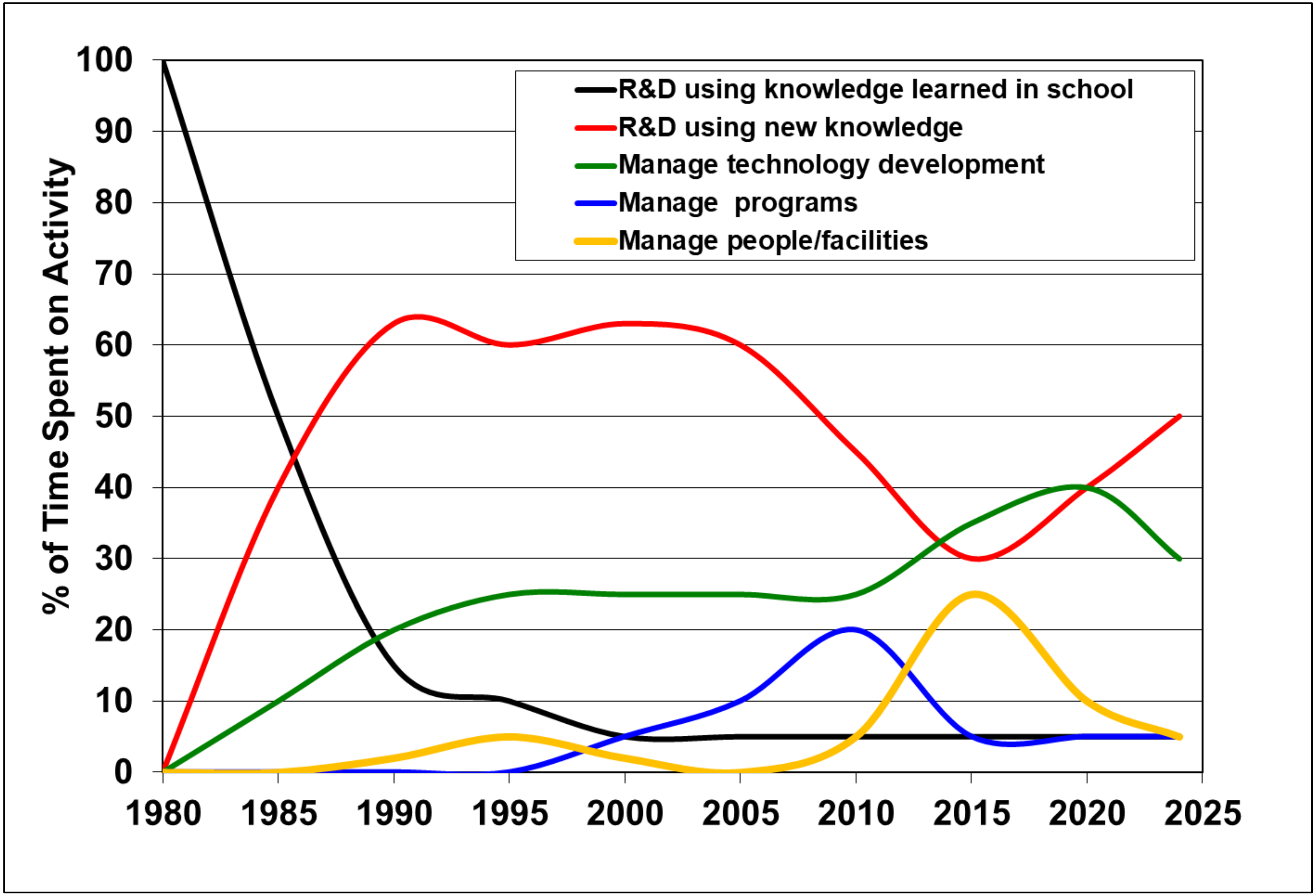
6,699,313	B2	3/2004	Coulter et al.
7,455,904	B2	11/2008	O'Keefe
2009/0087553	A1	4/2009	O'Keefe

Other fun stuff I've worked on or still work on

- Past (1980-1993)
  - Neutron transmutation doping of Si: Si +n → P
    - Neutron fluence, annealing, measurements
  - Materials for Nuclear Thermionic Space Power
  - Very high temperature electrical insulators for Nuclear Thermoelectric Space Power (1300K/100V/10 mils/7-years)
- Present
  - Coordinate intellectual property
  - Set up innovators internal research program
  - Review/revise company social media posts



Evolution of job responsibilities over time



Advantages of Careers in Industry

- Goal is development of a product
- Satisfaction of seeing your efforts make a difference
- Opportunities for patents, business development
- Challenge of not just doing science, but applying science to technology, then figuring out how to manufacture it in dynamic marketplace
- Challenge of learning how to perform R&D and scale-up under schedule, cost, equipment, quality, personnel, facilities constraints
- Varied career opportunities: science, technology, manufacturing, program or project management, group management, quality
- Many different projects; constant learning and agility needed
- Pay, bonus pool, stock options

Disadvantages of Careers in Industry

- Often minimal publications/presentations and interactions with non-company peers due to proprietary aspects, export controls, security issues
- Reduced likelihood of being recognized for your achievements from an academic perspective, e.g. awards, fellowships
- Focus on a defined goal (NOT curiosity driven)
- Limited freedom to pursue your personal interests
  - (caveat – see next part of talk!)
- (Almost) No sabbaticals, no tenure
- Need to rapidly reinvent yourself as technologies and business areas change

Part 2: Education activities are possible in industry

- Outreach program started at GA in 1992
- Many companies have education outreach programs
- Details and funding are highly dependent on the company, management support, and the initiative and desire of the individual scientist
- Why was I motivated to get involved and then more involved?
  - Opportunities, curiosity, frustration
  - 7-year unsuccessful effort to develop high Tc superconducting wire

1992-2003: Education modules, posters, presentations, reviews
"The journey of a thousand miles begins with one step" Lao Tzu

- 1992: GA education outreach program started
- 1993: Co-author: An Exploration of Materials Science Module; workshops
- 1996: Author: The Line of Resistance Module; presentations
- 1996: Author: Seeing the Light: Physics and Materials Science of Incandescent Light Bulb Module; presentations
- 1997: APS Teacher Scientist Alliance 5-day workshop K-6 science
- 1997: Author: It's a Colorful Life Module; workshops
- 1997: GA Sciences Education Foundation web site
- 1997: Reviewer for NSF Instructional Materials Development (IMD) panel
- 1998: Co-Author: Chromatics: The Science of Color
- 1998: Reviewer for LHS FOSS Electronics middle school unit
- 1998: Testified about state science standards to CA State Board of Education
- 1999: Presented 4 workshops at NSF sponsored workshop in U Wisconsin
- 1999: Wrote and managed science education petition to improve state science standards
- 2001: Presented 3 workshops at AAPT winter meeting in San Diego
- 1999-2004: Color, Light, Seasons posters
- 2001: Presented workshops at High School Teachers Day March & April APS
- 2002: LHS FOSS middle school unit on Force and Motion – design/review
- 2002: Chair – COV Review Panel for NSF IMD program
- 2003-2008: Reviewer for BSCS inquiry based high school science curriculum

Start

Catalyst

GA APS NSF

2004-Present: NSF/APS National Panels, FEd & COE chair, Phys21, EP3 GA Sciences Education Foundation president/chair

- 2004: Testified to CA state board of education on draft criteria for K-8
- 2004: NSF site review of GEMS Seeds of Science/Roots of Reading – LHS
- 2004-2007: APS Forum on Education
- 2005: Chair: review of Nat. Center for Learning/Teaching in Nanoscale S/E
- 2007: NSF site reviews of SRI Nanosense program
- 2007-present: President/Chair GA Sciences Education Foundation
- 2007: Steering committee: NSF Materials Education Workshop
- 2008-2011: Elected to 4-year chair line, APS Forum on Education
- 2010: Org. committee: 2nd workshop on graduate education in physics
- 2010-2012: APS Committee on Education
- 2012: NSF review panel for Cornell High Energy Synchrotron Source
- 2014: NSF review panel for National High Magnetic Field Laboratory
- 2014-2015: APS/AAPT Joint Task Force on Undergraduate Physics Programs-Phys21
- 2016-208: APS Development Advisory Committee
- 2016-2022: APS Effective Practices for Physics Programs (EP3)
- 2019-2020: APS Excellence in Physics Education Award selection committee
- 2020-2024: IUPAP Working Group 16: Physics and Industry, US Member
- 2022-2024: APS Committee on Education (2023 Chair)
- 2023-2026: APS EP3 Editorial Board (2025 Chair)
- 2023: APS Working Group on Vision/Mission/Values
- 2023-2024: Member-At-Large-U.S. Liaison Committee for the IUPAP

GA APS NSF

Moral

- **Stay open to opportunities**
- **Never say no (some of my peers disagree!)**
- **Do what you say you will do**
- **Do a good job**
- **If motivated/annoyed, then create/solve**
- **Utilize your unique skills and knowledge**

- **Let's look at some education highlights - posters**
  - Multiple representations
  - Relationships
  - Synthesize complex concepts into simple visible form

Color mixing - misconceptions

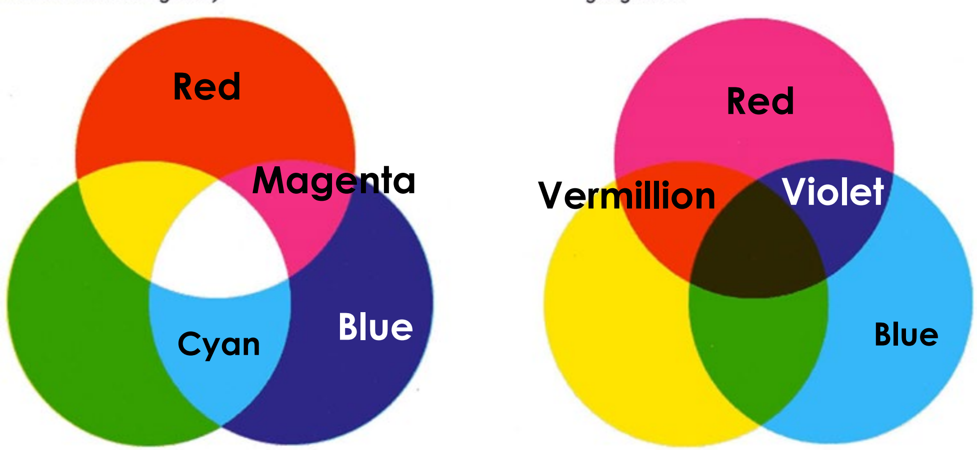
Curiosity Driven!

Confusion about primary colors

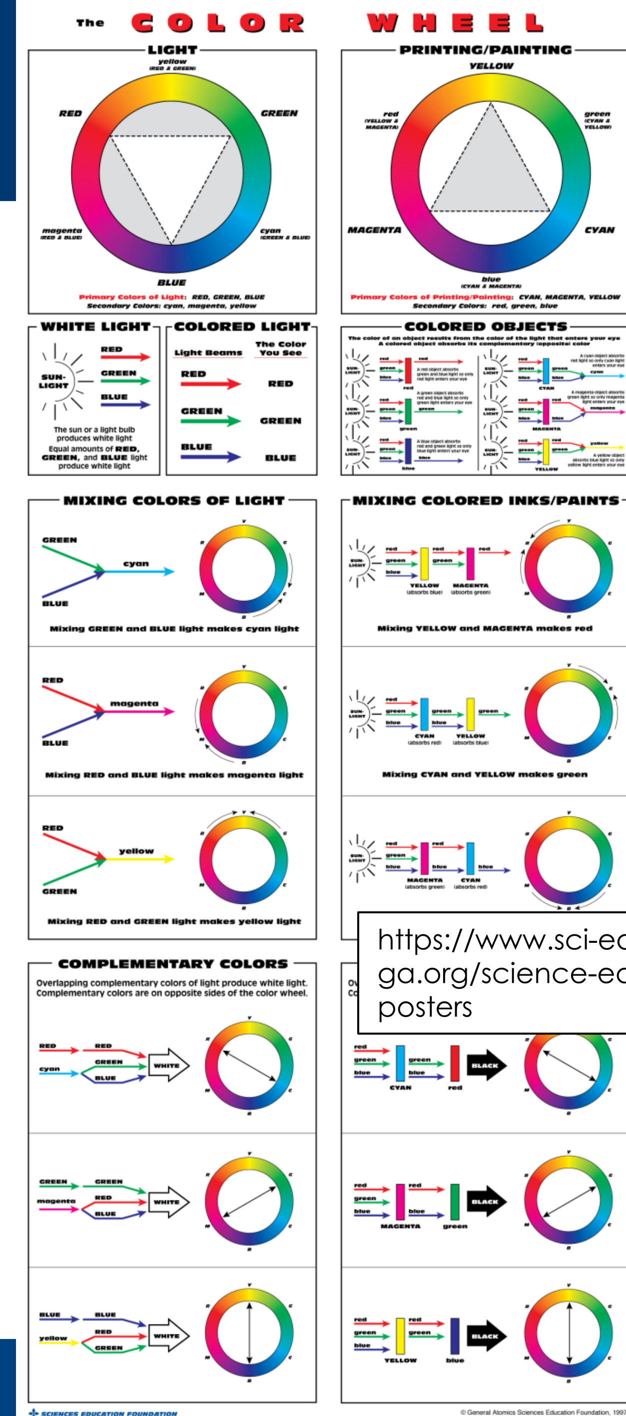
https://www.aps.org/publications/apsnews/200007/teachers-day.cfm

The result of mixing light colors together.
- *White is the result of superimposing the three beams of light, green, red, and blue, the primary light colors.*
- *The projection of two of these colors produces the secondary light colors: yellow (the result of superimposing green and red), magenta (the result of superimposing red and intense blue) and cyan blue (the result of superimposing intense blue and green).*

The result of mixing pigment colors together.
- *Black is the result of superimposing the three primary colors: yellow, red, and blue.*
- *Mixing yellow and red together produces vermilion.*
- *Red plus blue gives us violet.*
- *By combining blue with yellow we get green.*

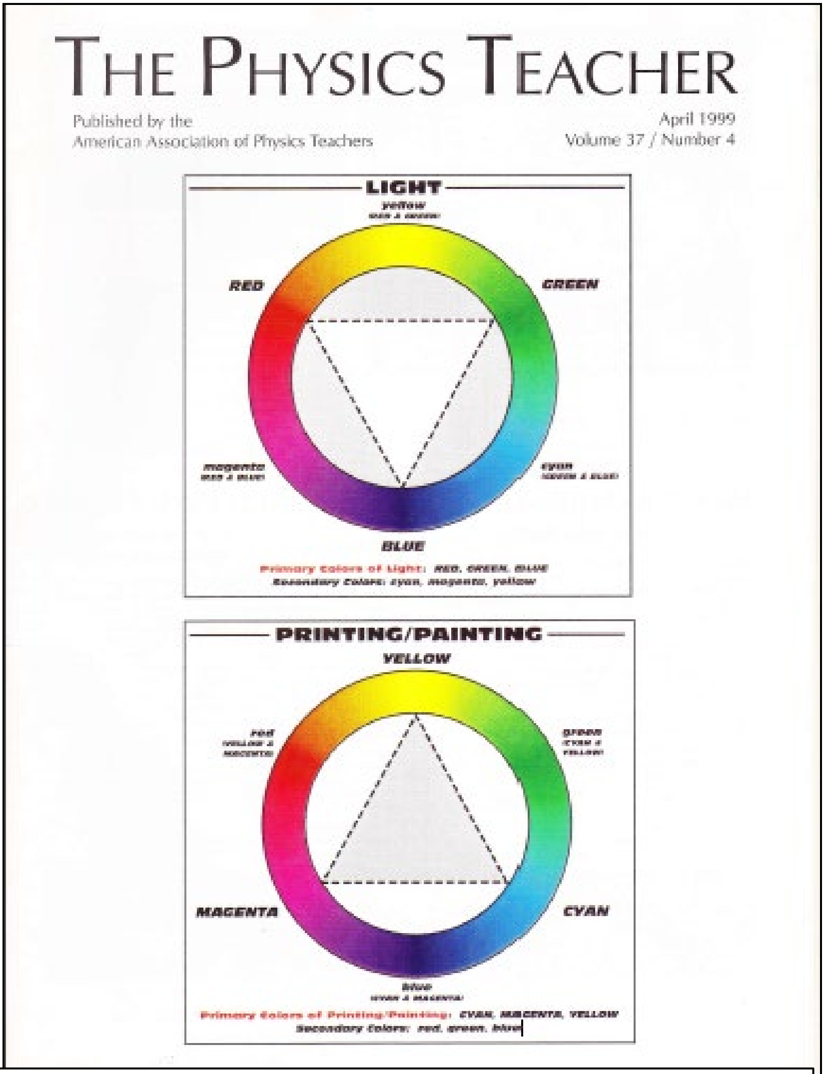


Barron's Art Handbooks: Mixing Colors 1. Watercolor



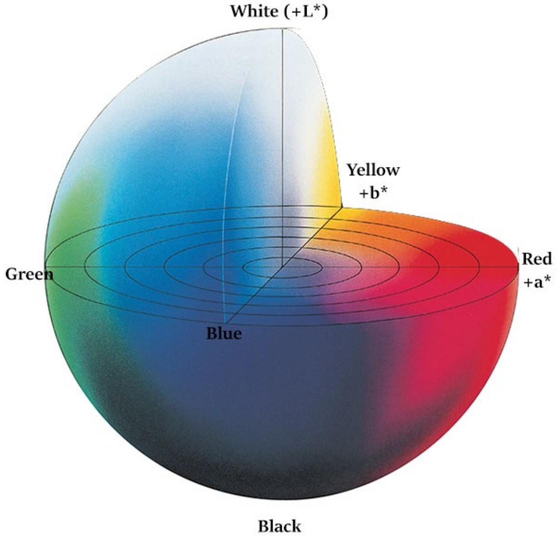
https://www.sci-ed-ga.org/science-education-posters

Publicity for the correct color wheels from the color wheel poster …

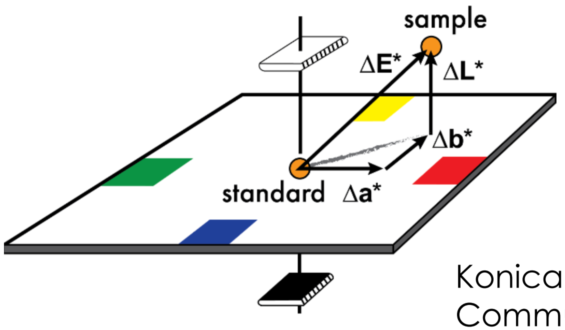


"Confusing Color Concepts Clarified," L. D. Woolf, The Physics Teacher 37, p.204 (1999)

Education informs industrial work!

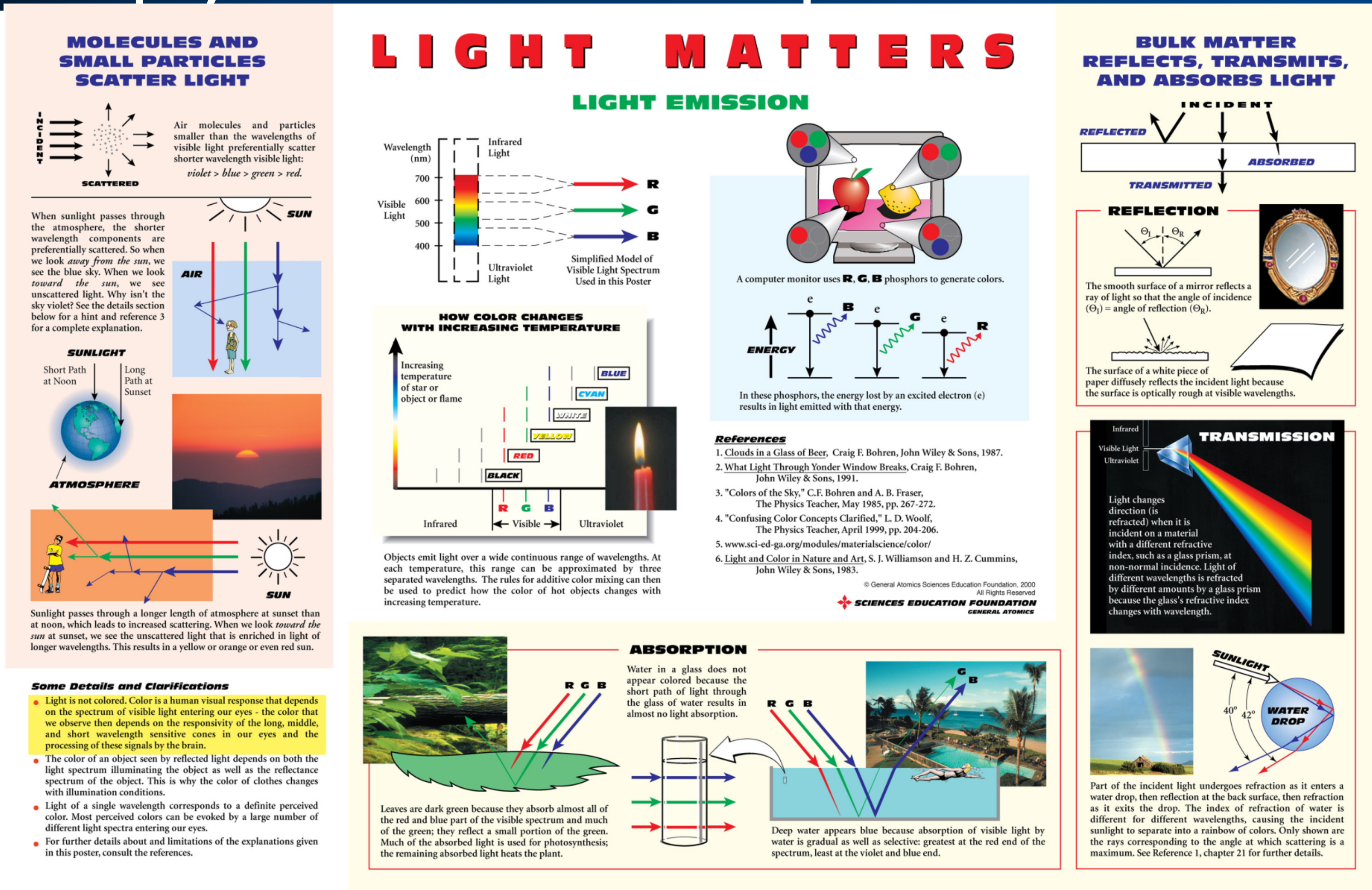


$$\Delta E_H = [(L_2-L_1)^2 + (a_2-a_1)^2 + (b_2-b_1)^2]^{1/2}$$



Konica Minolta "Precise Color Communication" booklet

Light Matters Poster:
More physics than color wheel poster



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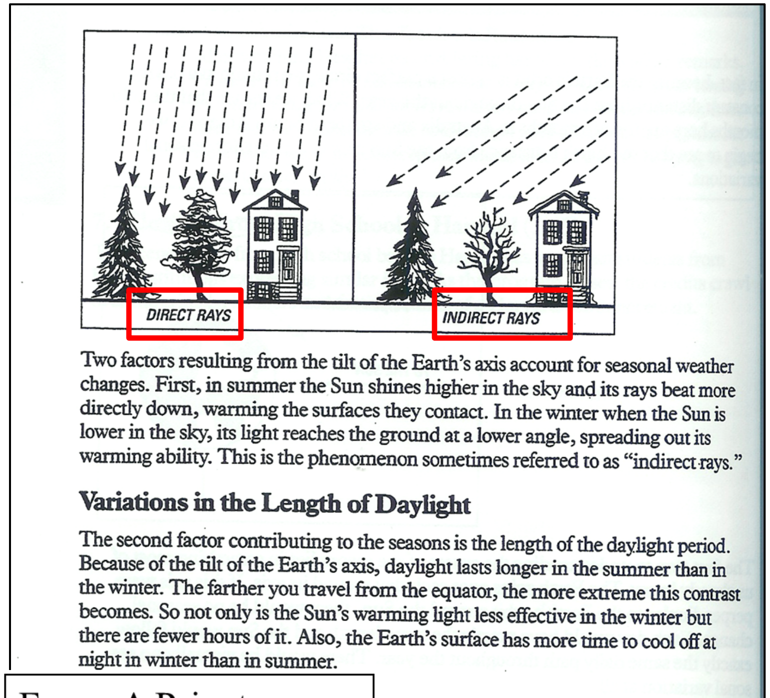
Misconceptions about seasons: scale, words

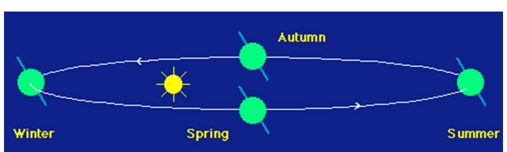


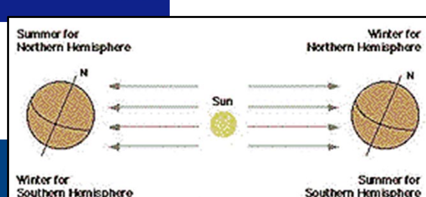
Two factors resulting from the tilt of the Earth's axis account for seasonal weather changes. First, in summer the Sun shines higher in the sky and its rays beat more directly down, warming the surfaces they contact. In the winter when the Sun is lower in the sky, its light reaches the ground at a lower angle, spreading out its warming ability. This is the phenomenon sometimes referred to as "indirect rays."

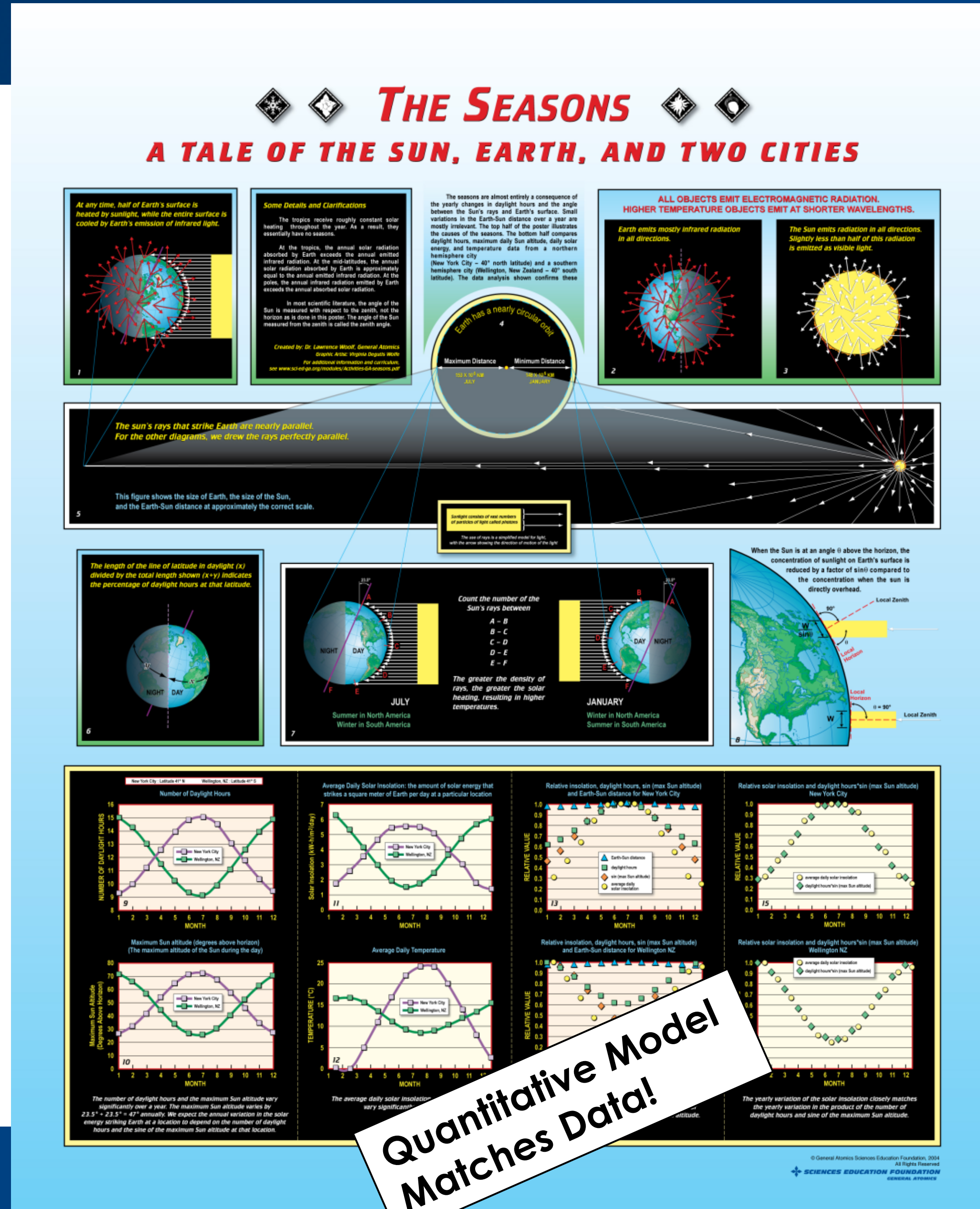
Variations in the Length of Daylight

The second factor contributing to the seasons is the length of the daylight period. Because of the tilt of the Earth's axis, daylight lasts longer in the summer than in the winter. The farther you travel from the equator, the more extreme this contrast becomes. So not only is the Sun's warming light less effective in the winter but there are fewer hours of it. Also, the Earth's surface has more time to cool off at night in winter than in summer.

From: A Private Universe Teacher's Guide, p. 18







Quantitative Model Matches Data!

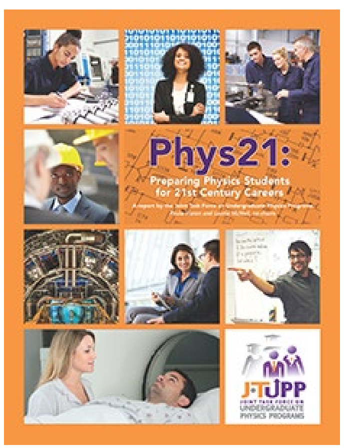
A guest appearance on The Big Bang Theory …

SCIENCES EDUCATION FOUNDATION
GENERAL ATOMICS

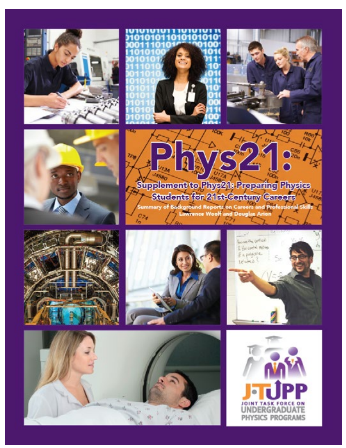
And another

…and another

Part 3: APS Involvement



Report



Supplement

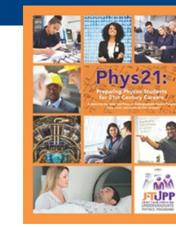
Joint Task Force on Undergraduate Physics Programs (J-TUPP)

What skills and knowledge should the next generation of undergraduate physics degree holders possess to be well prepared for a diverse set of careers?

compadre.org/phys21

Some slides include text from Prof. Laurie McNeil's talk at the 2017 APS March Meeting
https://www.compadre.org/JTUPP/docs/MarchMtg17.pptx

J-TUPP MEMBERSHIP

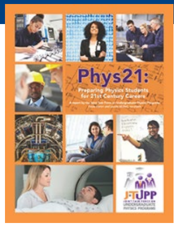


Paula Heron, co-chair, *University of Washington*
Laurie McNeil, co-chair, *University of North Carolina, Chapel Hill*

Douglas Arion, *Carthage College*
Walter Buell, *The Aerospace Corporation*
S. James Gates, *University of Maryland*
Sandeep Giri, *Google Inc.*
Elizabeth McCormack, *Bryn Mawr College*
Helen Quinn, *Stanford Linear Accelerator Center*
Quinton Williams, *Howard University*
Lawrence Woolf, *General Atomics Aeronautical Systems, Inc*

Society liaisons
Ted Hodapp, *APS*
Renee Michelle Goertzen, *APS*
Beth Cunningham, *AAPT*
Bob Hilborn, *AAPT*

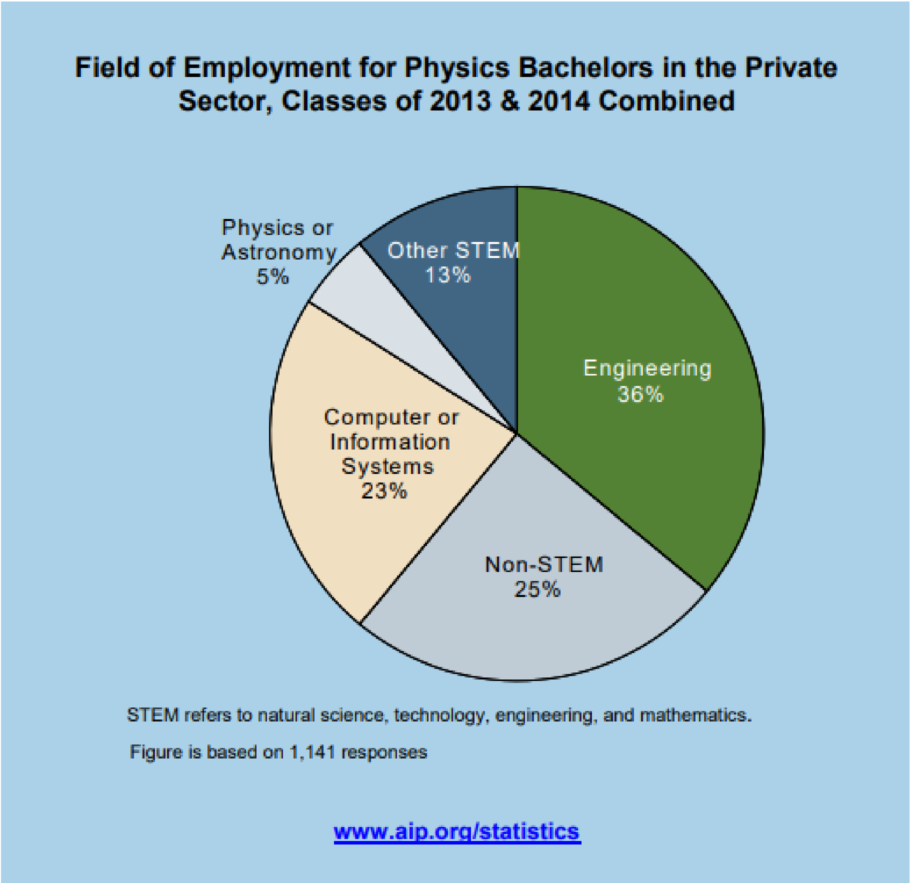
A FEW FACTS (changes year to year)

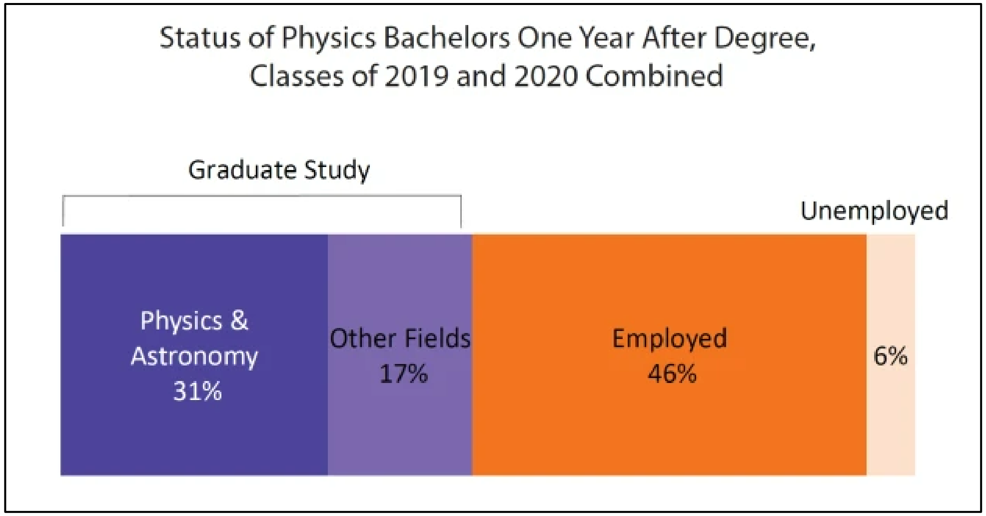


- 7,500 people graduate with bachelor's degrees in physics each year
- 350 people are hired as physics faculty members each year
- **5% of all physics bachelor's eventually end up as physics professors**
- **40% of bachelor's graduates enter the workforce immediately**
  - **61% work in the private sector**
  - 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 PhDs work in 4-year academic institutions**
  - **65% do not**

Various reports, AIP Statistical Research Center

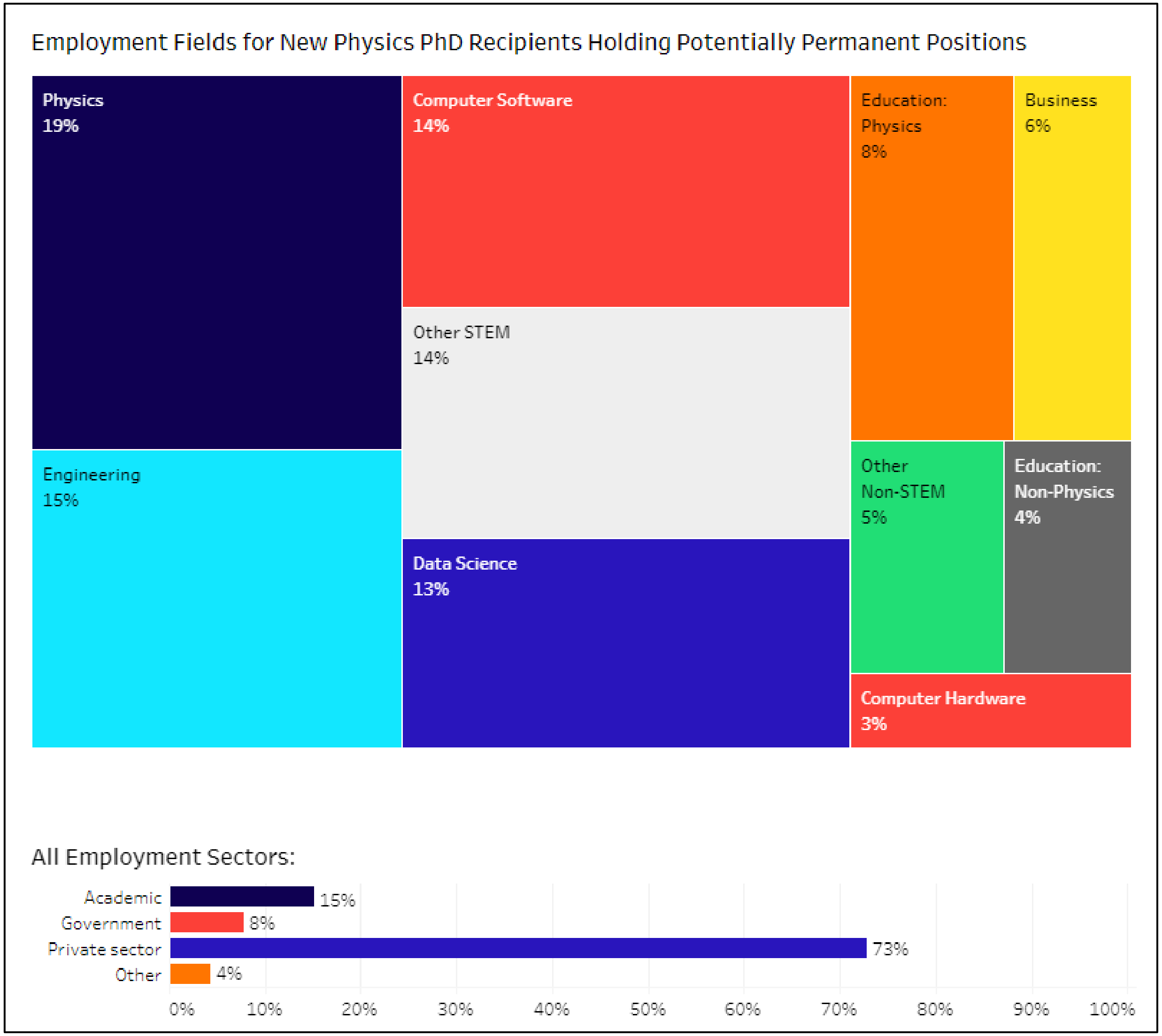
Physics Bachelors Employment





https://ww2.aip.org/statistics/status-of-physics-bachelors-one-year-after-degree-classes-of-2019-and-2020-combined

New Physics PhDs Holding Potentially Permanent Positions



https://ww2.aip.org/statistics/whos-hiring-physics-phds
Classes of 2016-2020

Common Job Titles
of Physics Bachelor's Recipients

Computer Hardware and Software

- Software Engineer
- Programmer
- Web Developer
- IT Consultant
- Systems Analyst
- Technical Support Staff
- Analyst

Research and Technical

- Research Assistant
- Research Associate
- Research Technician
- Lab Technician
- Lab Assistant
- Accelerator Operator
- Physical Sciences Technician

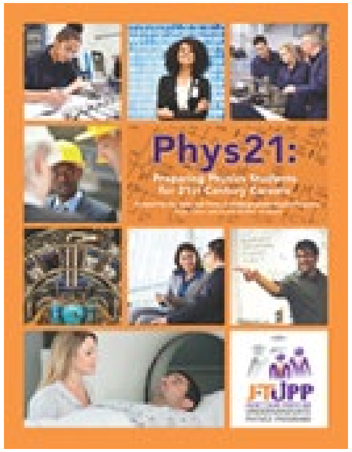
Education

- High School Physics Teacher
- High School Science Teacher
- Middle School Science Teacher

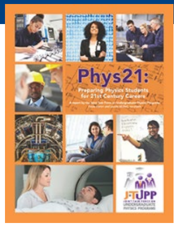
Engineering

- Systems Engineer
- Electrical Engineer
- Design Engineer
- Mechanical Engineer
- Project Engineer
- Optical Engineer
- Manufacturing Engineer
- Laser Engineer
- Associate Engineer
- Technical Services Engineer
- Application Engineer
- Development Engineer
- Engineering Technician
- Field Engineer
- Process Engineer
- Process Technician
- Product Engineer
- Product Manager
- Research Engineer
- Test Engineer
- General Engineer

This list is composed of common job titles identified by an AIP Statistical Research Center survey of physics bachelor's degree graduates from the classes of 2009 and 2010.



THE CHALLENGE FOR PHYSICS DEPARTMENTS



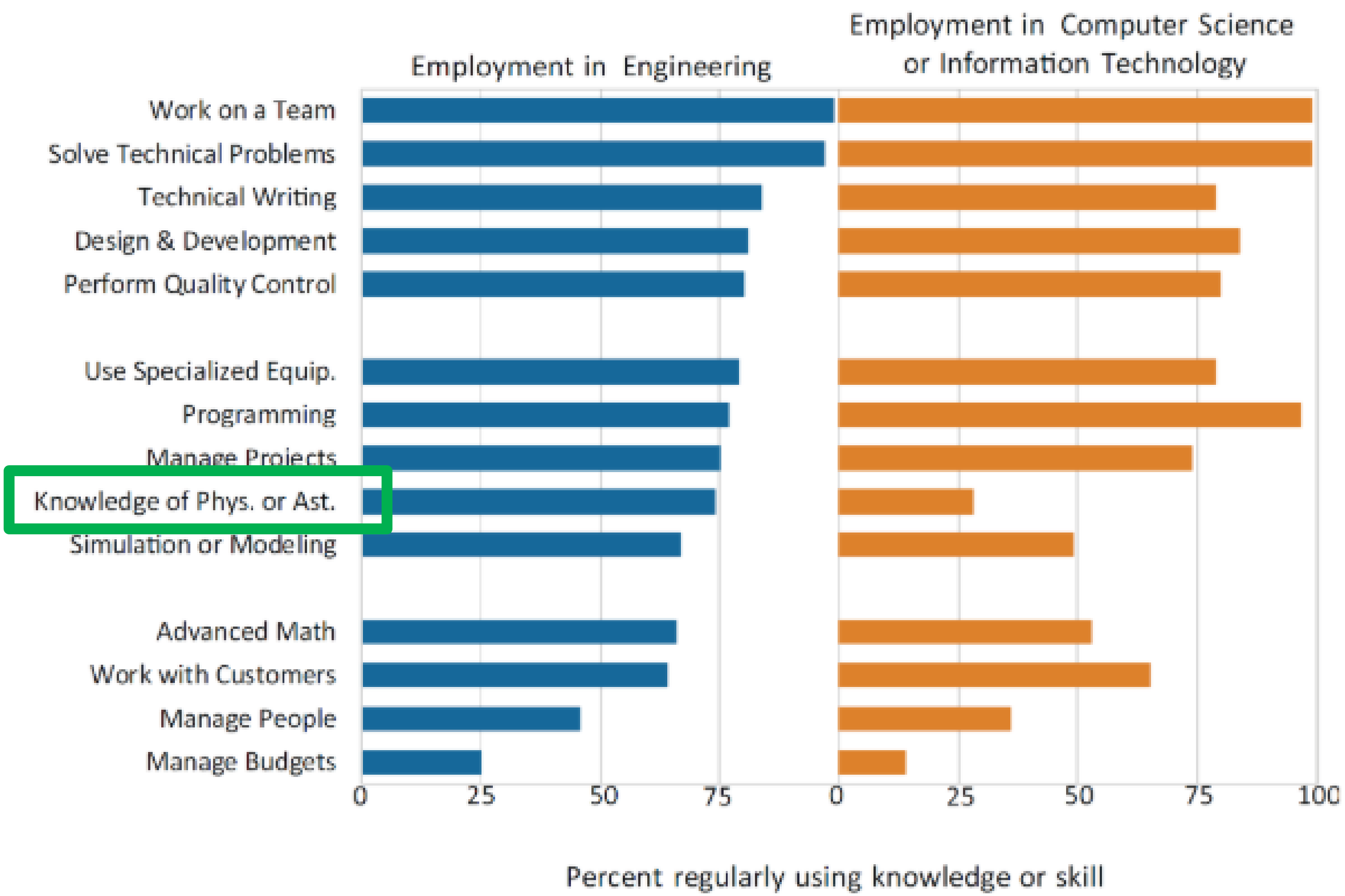
- To better prepare students for diverse careers, ***does not*** **mean**
  - **abandoning the rigorous technical education that makes a physicist a physicist**
  - **regarding your program as providing only vocational training**

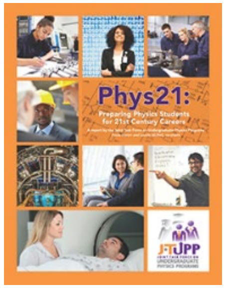
- **It *does* mean evaluating whether your department is doing its best to prepare students to compete with graduates in other fields (such as engineering) for desirable employment and career options**

- **It *does* mean that we should consider reframing education in the context of how it is used by our students**

From Prof. Laurie McNeil's talk at the 2017 APS March Meeting

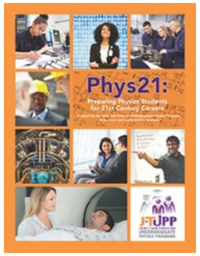
Knowledge and Skills Regularly Used by New Physics Bachelors Employed in the Private Sector, Classes of 2015 & 2016 Combined





Percentages represent the physics bachelors who indicated they use a knowledge or skill "daily," "weekly," or "monthly" on a four-point scale that also included "never or rarely."

Phys21 LEARNING GOALS FOR PHYSICS PROGRAMS: 1 of 2



p. 19-21

Physics-specific knowledge, *e.g.*

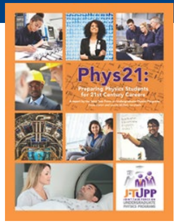
- Apply basic laws of physics
- Solve problems involving multiple areas of physics
- Solve multidisciplinary problems that link physics with other disciplines
- Investigate how physics concepts are used in modern technology

Scientific and technical skills, *e.g.*

- Solve both well-posed and ill-posed problems through experiments, simulations, models
- Determine follow-on investigations
- Identify resource needs
- Competencies: instrumentation, computation, industry standard software, coding, data analytics

J-TUPP

Phys21 LEARNING GOALS FOR PHYSICS PROGRAMS: 2 of 2



p. 19-21

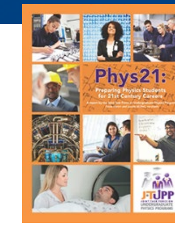
Communication skills, *e.g.*

- Communicate orally and in writing with audiences with a wide range of technical or non-technical backgrounds
- Organize and communicate ideas using words, mathematical equations, tables, graphs, pictures, diagrams
- Listening, discussing, persuading, assessing, understanding, teaching

Professional/workplace skills, *e.g.*

- Collegiality and collaboration in diverse teams
- Critical life skills: time management, listening, optimism, responsibility, perseverance, ethical behavior
- Awareness of career opportunities and pathways for physics graduates
- Awareness of standard practices for effective resumes and job interviews

How to Become a Successful Physicist



- **Carl Wieman, “The Nature of Physics Problem Solving”**
- [Physics Today 75 (9) 46-52 (2022)]
    - “29 sets of questions that students and physicists need to ask themselves during the research process. The answers at each step allow them to make the 29 decisions needed to solve a physics problem”
        - Selection and Planning (1-9)
        - Decisions that establish the specifics needed to solve the problem (10-15)
        - Analysis and Conclusions (16-26)
        - Decisions about the significance of the work and how to communicate the results (27-29)

Origin of the EP3 Guide

EP3 Effective Practices for Physics Programs

Genesis of the EP3 Guide

Charge from the APS Council:

*Provide a **living** physics-community-based resource to assist programs in developing a culture of continuous self-improvement, in keeping with their individual mission, context, and institutional type*

APS Council approved formation of the Best Practices for Undergraduate Physics Programs (BPUPP) Task Force in 2015 to create this Guide

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EP3 Effective Practices for Physics Programs

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APS Advancing Physics

AAPT PHYSICS EDUCATION

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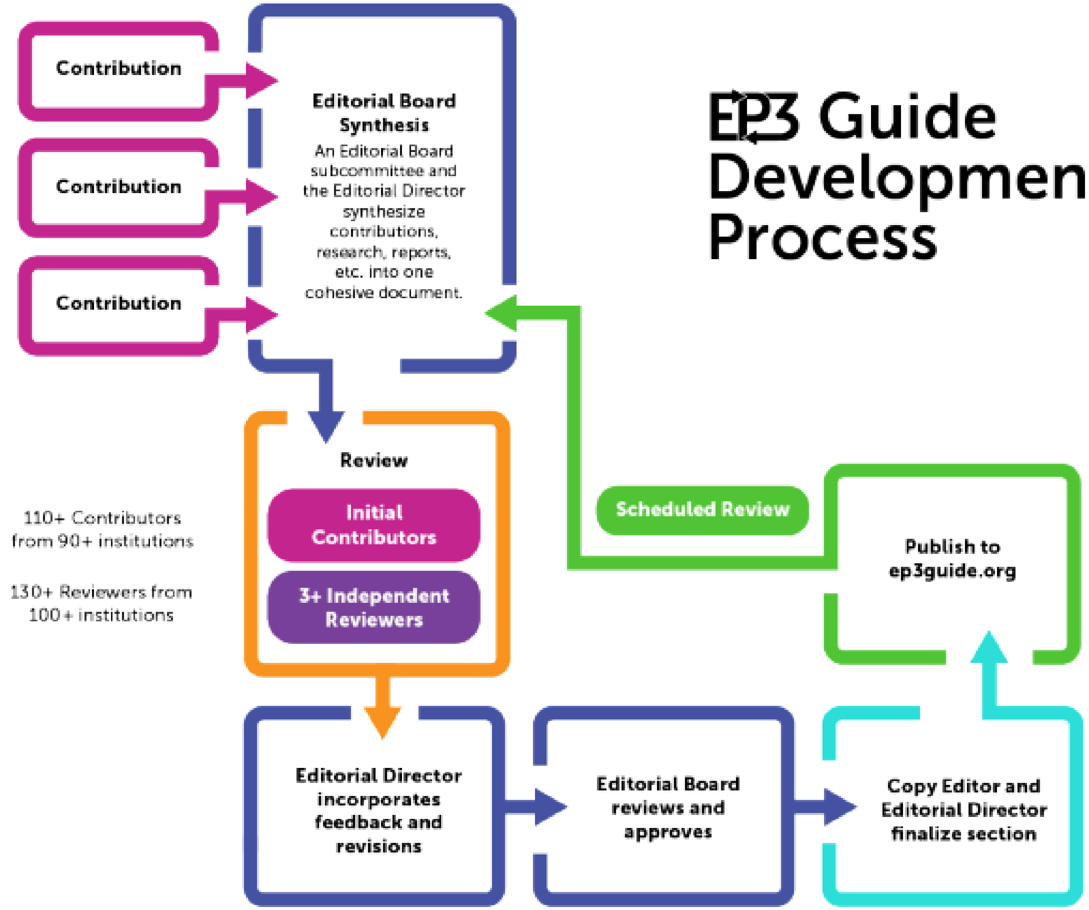
SCIENCES EDUCATION FOUNDATION
GENERAL ATOMICS

EP3 Process

Effective
Practices
for Physics
Programs

Section Development

EP3 Guide Development Process



Effective Practices Guide Sections

Effective Practices for Physics Programs

Developed and reviewed by experts in the physics community, these sections have been approved by the task force. They address a wide range of topics relevant to ensuring a thriving physics program, including actionable practices and implementation strategies.

Recruiting of Undergraduate Physics Majors	Retention of Undergraduate Physics Majors	Advising and Mentoring of Students	Career Preparation
Preparing Students for Graduate School in Physics and Related Fields	Undergraduate Research	Internships	Capstone Experiences
Introductory Courses for STEM Majors	Introductory Courses for Life Sciences Majors	Upper-Level Physics Curriculum	Courses for Non-STEM Majors
Instructional Laboratories and Experimental Skills	Computational Skills	High School Physics Teacher Preparation	Degree Tracks
Dual-Degree Programs	How to Be an Effective Chair	How to Select and Use Various Assessment Methods in Your Program	How to Create and Use a Strategic Plan
How to Create and Use Foundational Documents	Departmental Culture and Climate	Equity, Diversity, and Inclusion	Ethics
How to Undertake an Undergraduate Program Review	How to Serve as an Undergraduate Program Reviewer	The Physical Environment: Encouraging Collaboration and Learning	**7 more sections by the end of 2024**

EP3 Guide – Career Preparation Section Themes and Effective Practices

Description | Benefits | Effective Practices | Assessments | Resources | Evidence

3 Themes

1. Communicate to and educate students about a variety of career options
2. Provide students with on-campus experiences that explicitly teach skills and knowledge relevant to future careers
3. Provide students with off-campus learning experiences that explicitly teach skills and knowledge relevant to future careers

3. Provide students with off-campus learning experiences that explicitly teach skills and knowledge relevant to future careers

A. Create connections between your physics program and employers, professionals, and alumni

B. Create infrastructure that will allow students to take part in summer research experiences and/or internships in local companies

C. Engage foundations, non-profits, government entities, and your development or fundraising office to promote student innovation

EP3 Guide – Career Preparation Section
Implementation Strategies for 1 Effective Practice

A. **Create connections between your physics program and employers, professionals, and alumni**

i. Connect local physics and technology professionals with faculty to provide opportunities for student internships.

ii. Pair students with mentors in private-sector careers, e.g., see the IMPact program under Resources.

iii. Provide students and faculty with opportunities to take tours of local companies and other places of employment.

iv. Support students applying for jobs, especially students from marginalized groups, in finding workplaces where they will be supported.

v. Invite alumni to interact with current students as informal or formal mentors, e.g., by serving as colloquium speakers, attending departmental events, inviting students to visit the alumni's workplace, or judging student posters or presentations.

vi. Educate members of the private sector about things physics students can do, technical skills and knowledge students gain from a physics degree, and ways students' problem-solving abilities can benefit companies, e.g., by visiting their businesses, hosting department open houses, or creating industry advisory boards.

6 Implementation Strategies (menu of options)

Career Preparation Resources

- Phys21 Report and Supplement
  - www.compadre.org/JTUPP/
- EP3 Guide
  - https://ep3guide.org/
- AIP Career Pathways Project
  - www.spsnational.org/career-resources/career-pathways
- APS Careers in Physics
  - www.aps.org/careers/index.cfm
- How to become a successful physicist, Carl Wieman
  - Physics Today 75 (9), 46-52 (2022)
- International Career Resources
  - https://iupap-corporate-associate-members.web.cern.ch/node/4

Questions?

- What does an industrial physicist do?
  - Lots of interesting challenging work
- Can you get involved in physics education in industry?
  - Yes, just begin the journey
- What is the best way to prepare undergraduate physics students for careers?
  - Purposely. Consider the many resources available such as Phys21 and EP3
- How can APS play a major role in your professional life?
  - By providing opportunities to make an impact, and work with interesting people (in addition to providing a forum for talks)
- How are these questions related?
  - Cross-fertilization