Creating Rewarding Careers in Industrial Physics and Physics Education

San Diego State University
Physics Colloquium

October 4, 2019

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

Outline

- Part 1: Career in industry
- Part 2: Education path
- Part 3: Preparing students for careers – Phys21

Limited highlights reel

- 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 are these questions related?

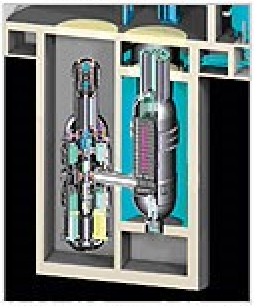
Part 1: My career in 4 snapshots


14-MW TRIGA® Reactor in Romania


Inside DII-D Fusion Device


LYNX™ Radar System


High-speed Railroad Catenary Maintenance Vehicle


Modular Helium-cooled Reactor

- **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 for 37 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


Aerial View of General Atomics' San Diego Facility

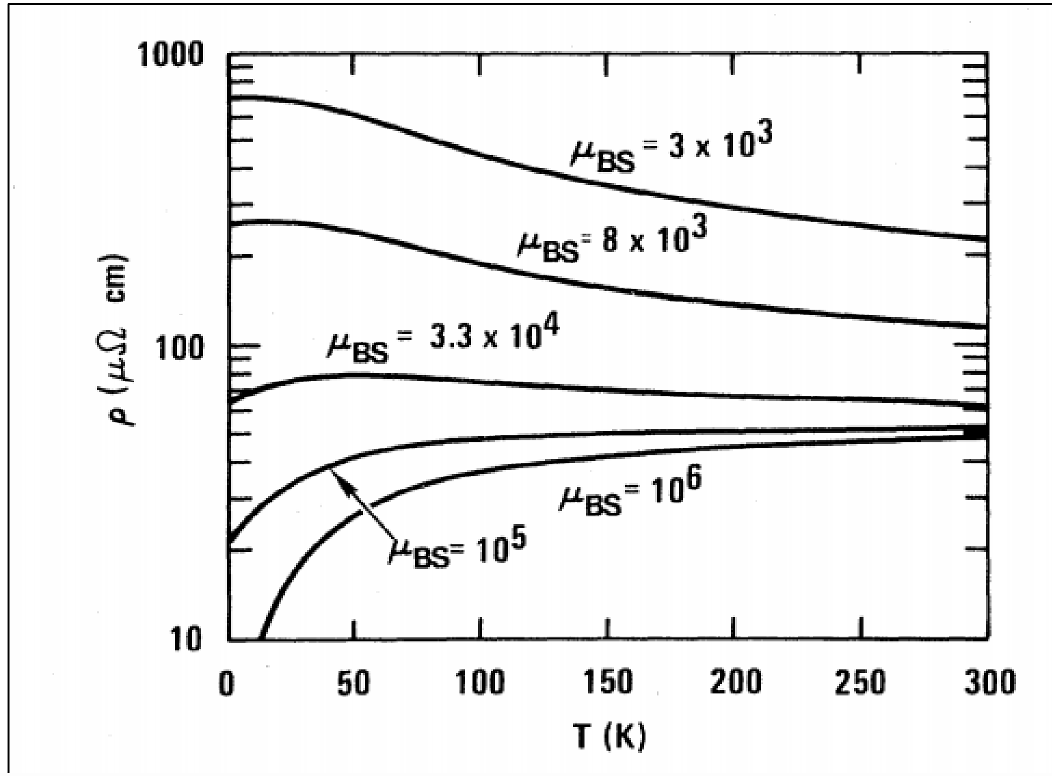

Predator® Unmanned Aerial Vehicle (UAV)


Maglev Transportation


Electromagnetic Aircraft Launch System (EMALS)


High-power AC Propulsion System

Graphite and intercalated graphite fibers- potential lightweight electrical conductors



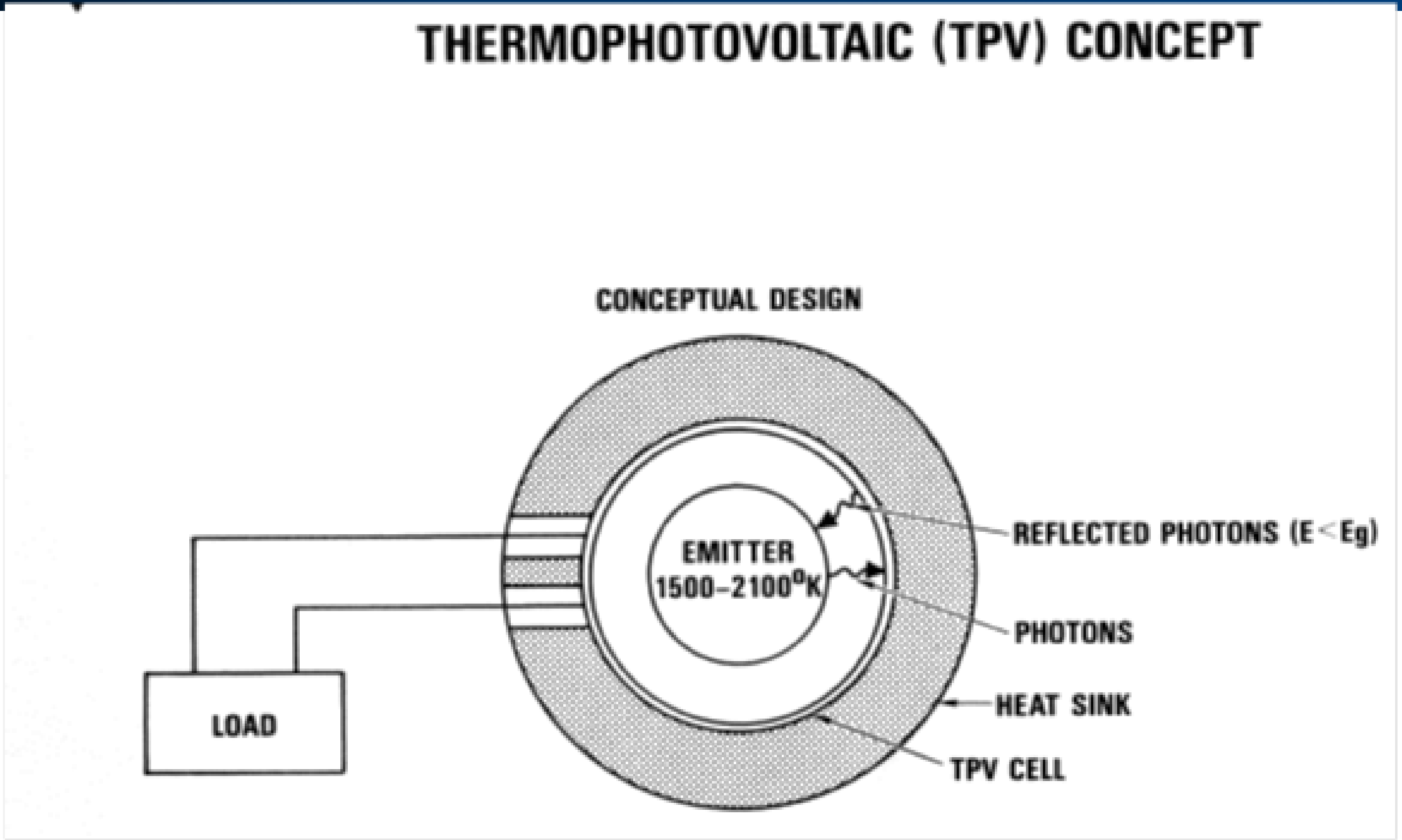
PHYSICAL REVIEW B VOLUME 30, NUMBER 2 15 JULY 1984

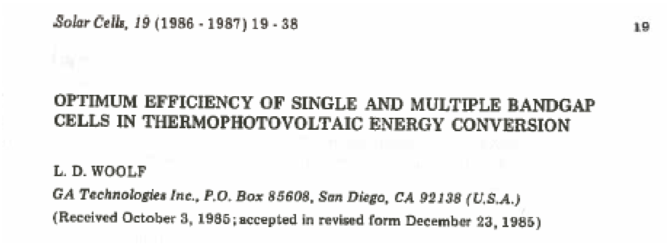
Electrical transport properties of benzene-derived graphite fibers

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)

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

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





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)

High temperature materials + optical properties →

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

Graduate school + ceramic materials + thick film coatings →

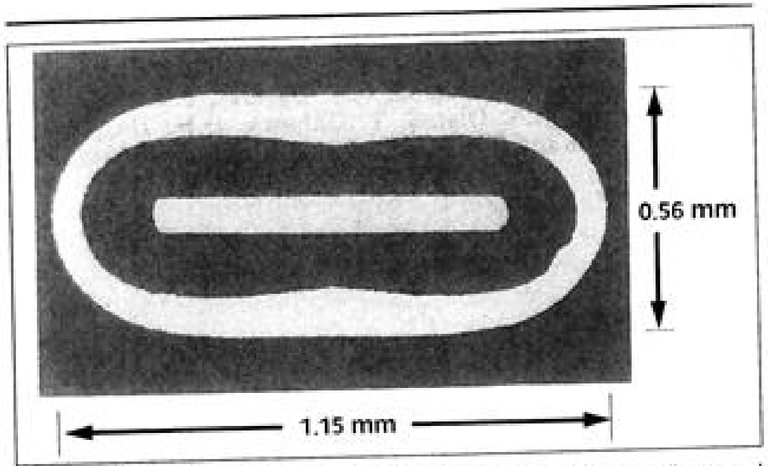


Fig. 4. Polished transverse cross section of an as-coated silver and superconductor coated silver tape.

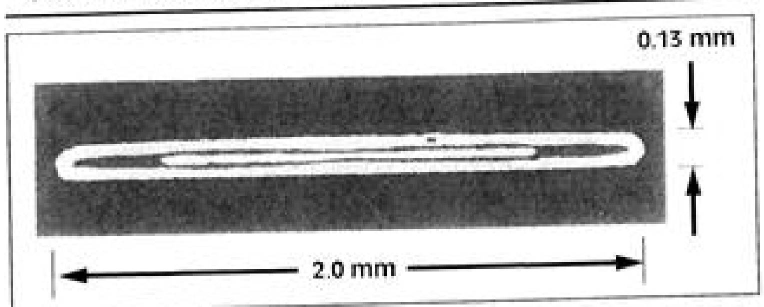


Fig. 5. Polished transverse cross section of a fully processed silver and superconductor coated silver tape.

- 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

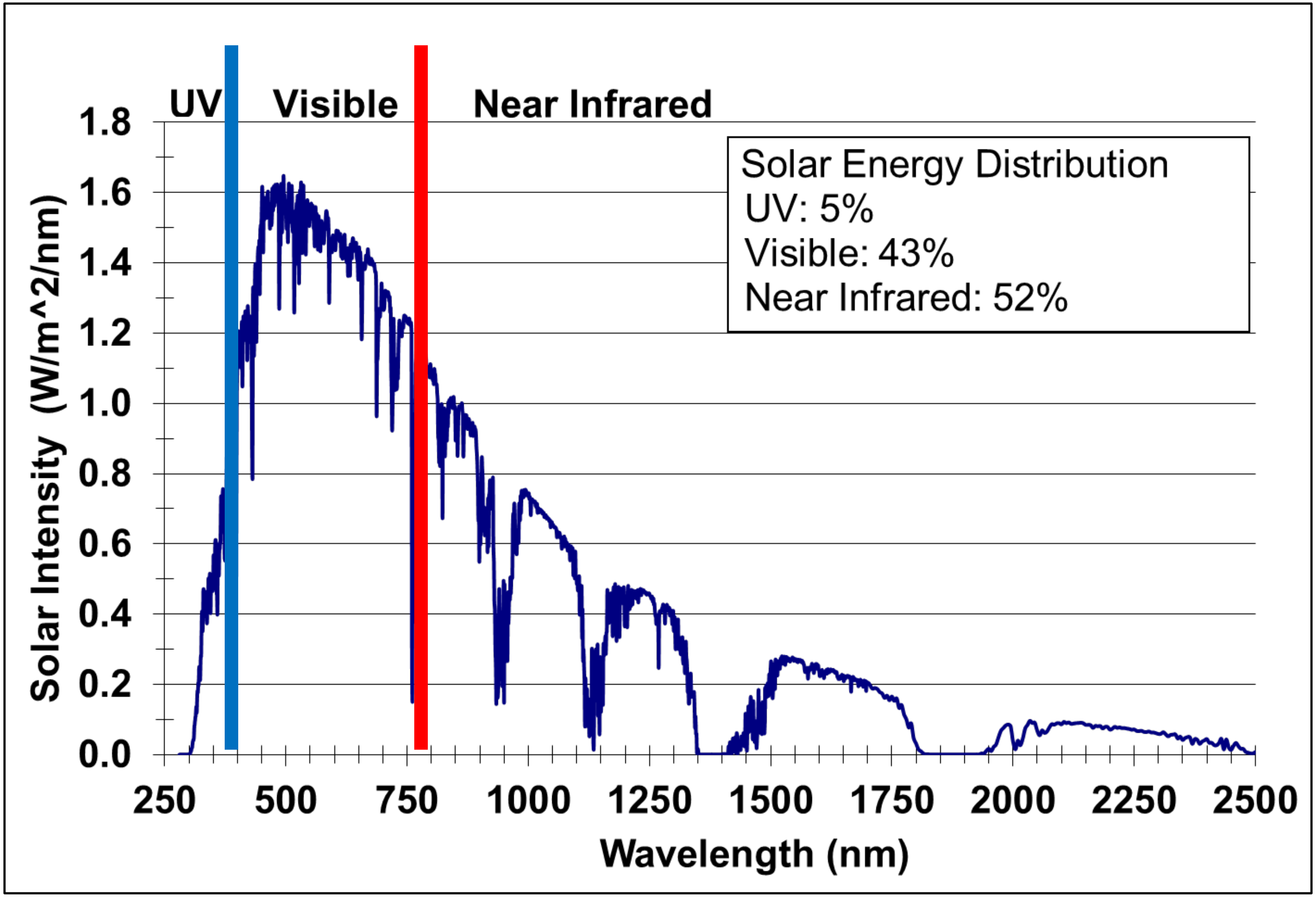
Initially great story of black cool paint ~2008

Thin film coatings + optical properties →

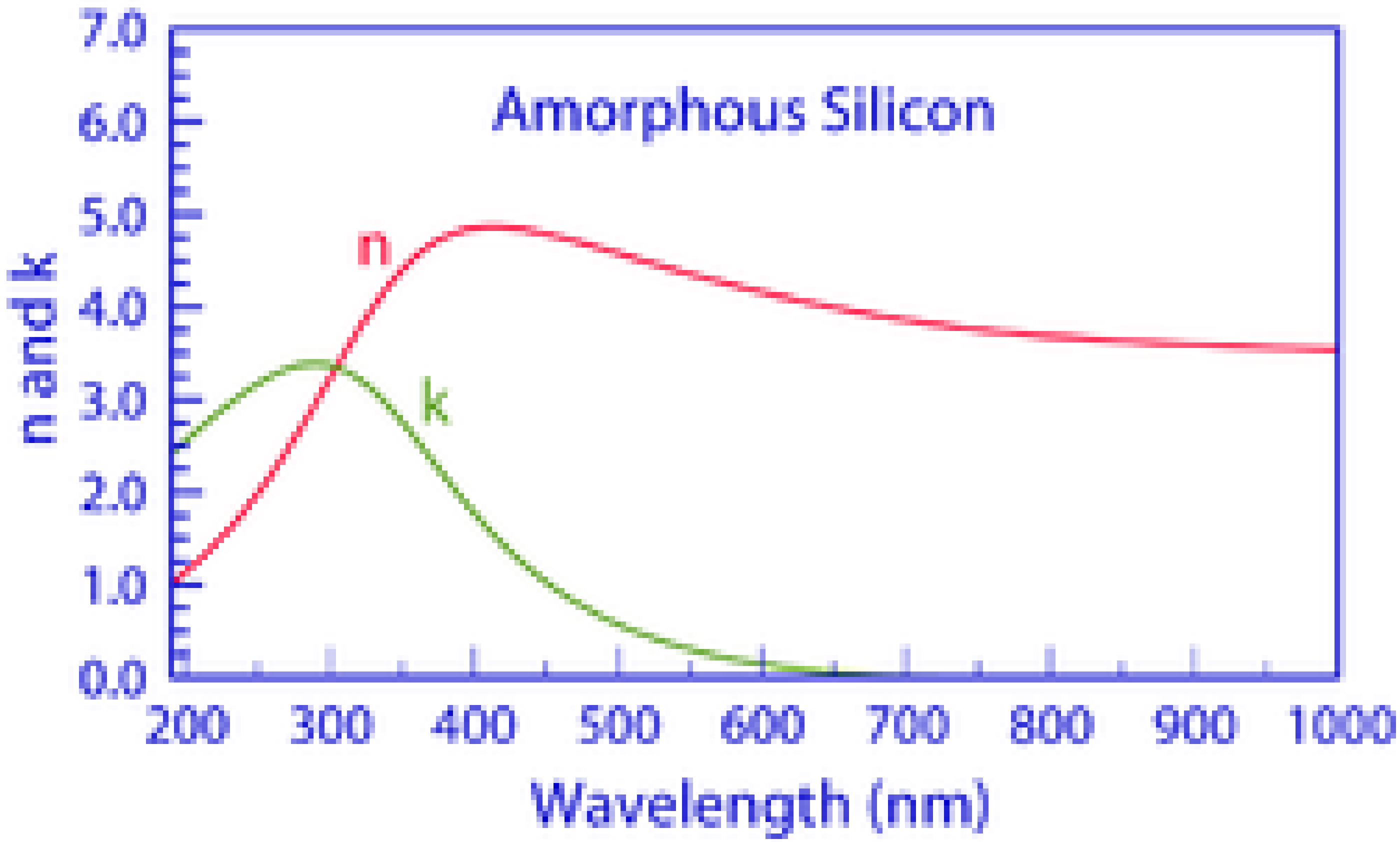
95603. Automotive Coating Reflectivity Standards. (Draft regulation for 2012-2016)

(a) The opaque surfaces of new passenger cars, light-duty trucks, and medium duty vehicles less than or equal to 10,000 pounds must reflect at least 20 percent of the impinging direct solar energy.

Cool paints have high near-IR reflectance (700-2500nm) to reduce solar heating



Use of optical properties of Si to make a cool coating



Differences in n: reflection
k: absorption

Finally sad story of black cool paint

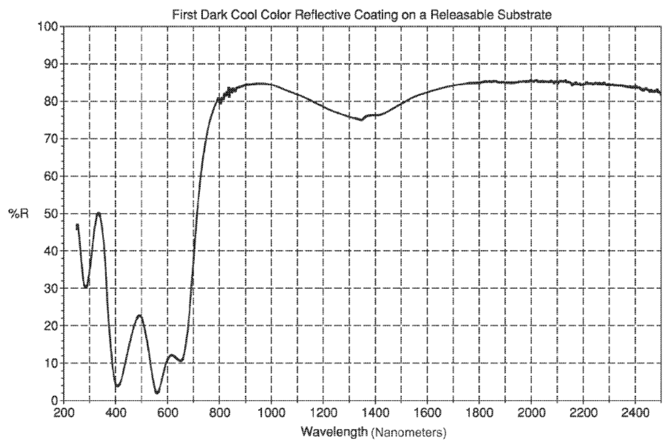


FIG. 10

U.S. Patent Jan. 13, 2015 Sheet 6 of 8 US 8,932,724 B2

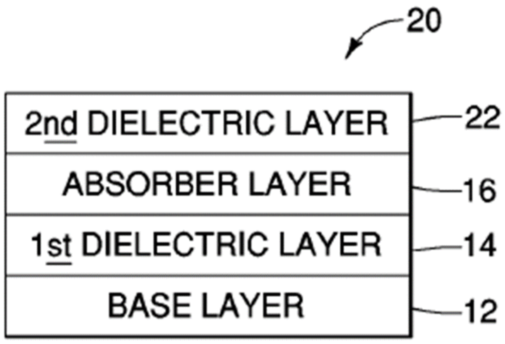


FIG. 2

(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**

(75) Inventor: **Lawrence D. Woolf**, Carlsbad, CA (US)

(73) Assignee: **General Atomics**, San Diego, CA (US)

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 PUBLICATIONS

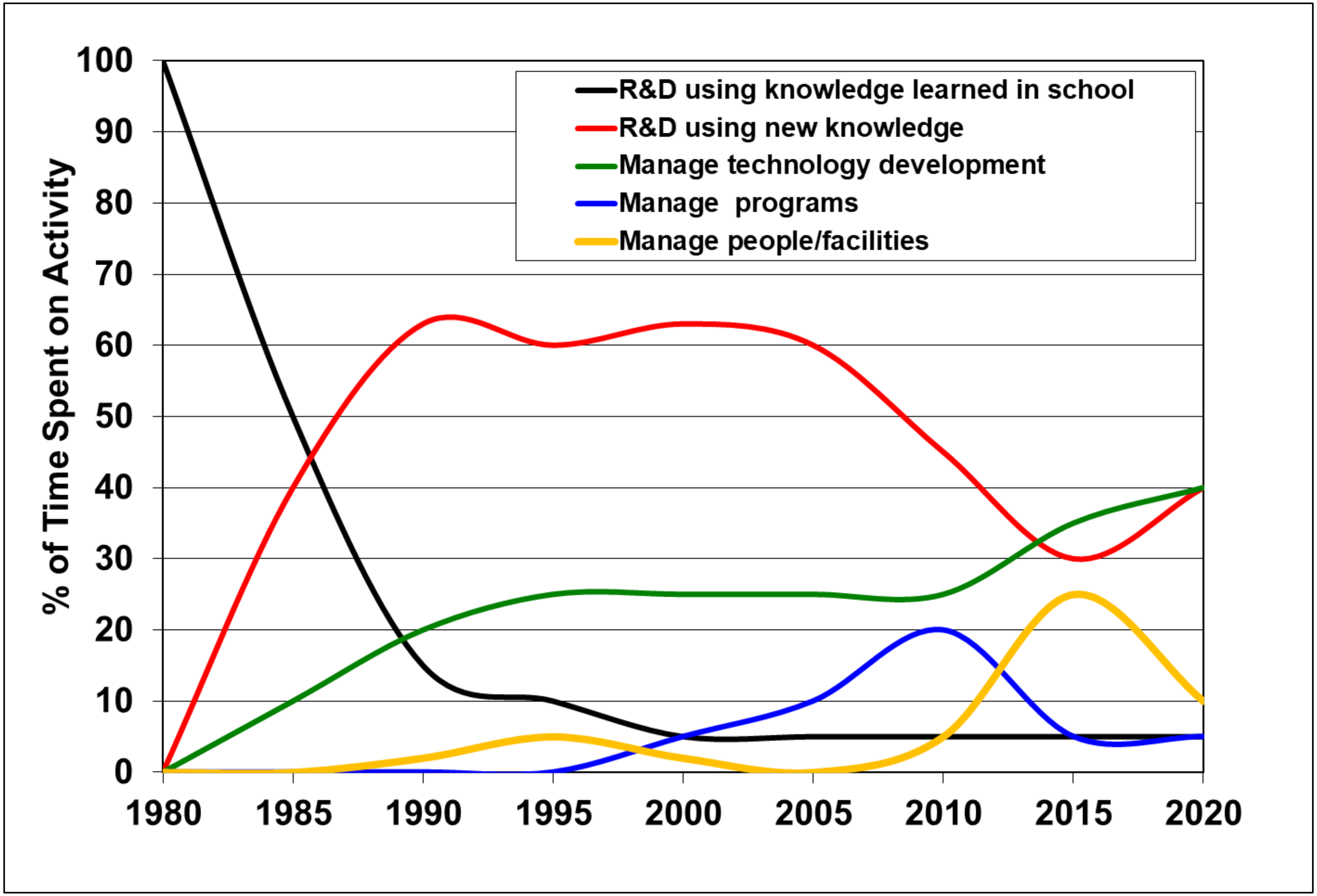
Park et al. "Band Gap Engineering of Amorphous Silicon Quantum

http://www.newscientist.com/blogs/shortsharpscience/2009/03/california-to-ban-sale-of-blac.html

Based on input from the automotive industry, paint, pigment suppliers, and comments from a public workshop held on March 12th [2009], ARB staff has determined that a clear path to achieve the levels of solar reflectivity for the darker colors has not yet been identified. *Now we're challenging inventors to create paint in all colors to reflect heat from the sun. Yes, even black paint.*

Stanley Young
California Air Resources Board

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 to people
- Opportunities for patents, business development
- Challenge of not just doing science, but applying science to technology, then figuring out how to commercialize 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 management, group management, quality
- Many different projects; constant learning needed
- Pay, bonus pool, stock options

Disadvantages of Careers in Industry

- Often minimal publications/presentations and interactions with peers due to proprietary, 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
- (Almost) No sabbaticals, no tenure
- Need to rapidly reinvent yourself as technologies and business areas change

My15 Point Guide to Success

1. Be responsive – return phone calls and emails promptly. When asked to do something, do it on time – be sure to ask when it should be done. Document requests and responses in writing.
2. Become the world expert in your particular area.
3. Continually expand the depth and breadth of your knowledge and skills.
4. Utilize all information resources available - books, science magazines, web sites, search engines, search services, colleagues, patents, trade magazines, catalogs, sales reps, conferences.
5. Get involved with or develop projects that have a high probability of contributing to the company's success.

My 15 Point Guide to Success

6. Understand and be aware of project constraints such as your personnel and company capabilities, competitor's strengths, and customer needs.
7. Innovate continuously. Always push your envelope as well as the science and technology envelope. Stay uncomfortable with what your skills and knowledge are.
8. Document your work in manner that *is actionable* and can be easily understood by a co-worker a year from now. Use spreadsheets, tables and charts to convey your results in a concise, visual, and easy-to-understand manner.
9. Make sure that you learn something useful from any tests or experiments that you perform. These results should form the basis for future tests.
10. Learn from your mistakes. Don't repeat them.

Remember 8 when I discuss the Phys21 Supplement

My 15 Point Guide to Success

11. Don't believe everything you are told, even if it is company lore or told to you by an expert. Be skeptical.
12. Enjoy your work.
13. Treat everyone you work with (above and below you) with respect. Thank them for their work. Acknowledge their contributions whenever possible. Keep them informed as to what you are doing and why you are doing it.
14. Have a sense of humor.
15. Develop a unique and necessary skill and knowledge set that complements those of your co-workers and greatly increases the value of your project/team. Be indispensible.

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 arose
  - 7 year unsuccessful effort to develop high Tc superconducting wire

1993-2001: Education modules, posters, presentations, reviews
“The journey of a thousand miles begins with one step” Lao Tzu

- 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 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 education:
- 2001: Presented 3 4-hour workshops at AAPT winter meeting in San Diego
- 1999-2004: Color, Light, Seasons posters
- 2001: Presented workshop at High School Teachers Day April APS

APS Strand NSF Strand

2002-Present: NSF/APS National Panels, FEd chair, Foundation president

- 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
- 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
- 2005: Chair: review of Nat. Center for Learning/Teaching in Nanoscale S/E
  2007: Site review of SRI Nanosense program for NSF
- 2007: President/Chair GA Sciences Education Foundation
- 2007: Steering committee: NSF Materials Education Workshop
- 2008: Elected to chair line, APS Forum on Education
- 2010: Org. committee: 2nd workshop on graduate education in physics
- 2010: 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: APS/AAPT Joint Task Force on Undergraduate Physics Programs-Phys21
- 2016: APS Development Advisory Committee
- 2016: APS Best Practices for Undergraduate Physics Programs (EP3)
- 2019: APS Excellence in Physics Education Award selection committee

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 visual curriculum – posters**
  - Multiple representations
  - Relationships
  - Context

Color mixing

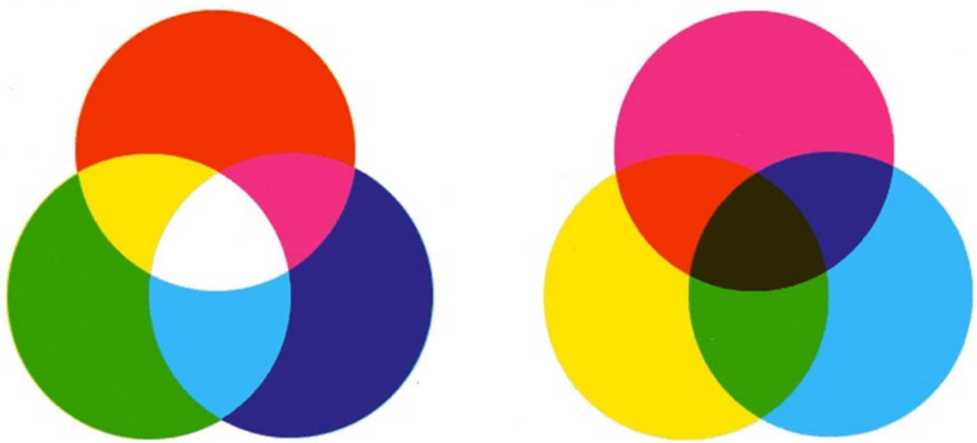
Confusion about primary colors and poor model – same for light and pigment

The result of mixing light colors together.

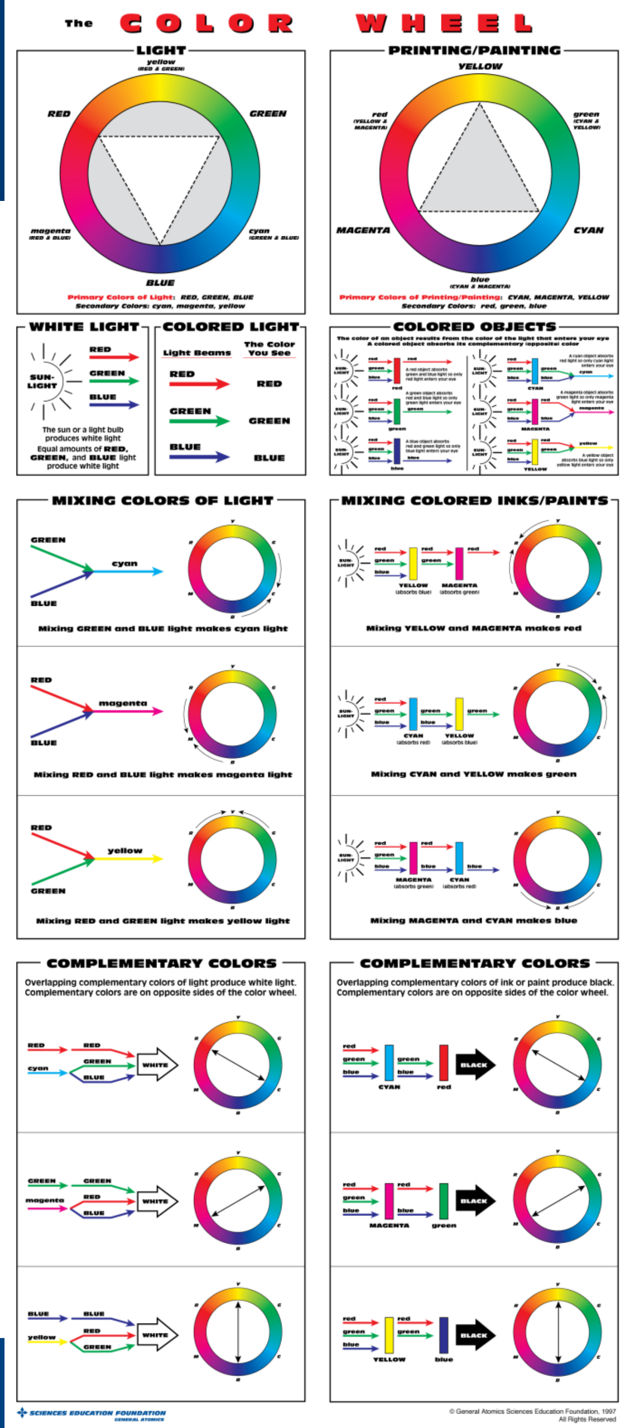
- *White is the result of superimposing the three beams of light, green, red, and blue, the primary light colors.*
- *The projection of two of these colors produces the secondary light colors: yellow (the result of superimposing green and red), magenta (the result of superimposing red and intense blue)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

The result of mixing pigment colors together.

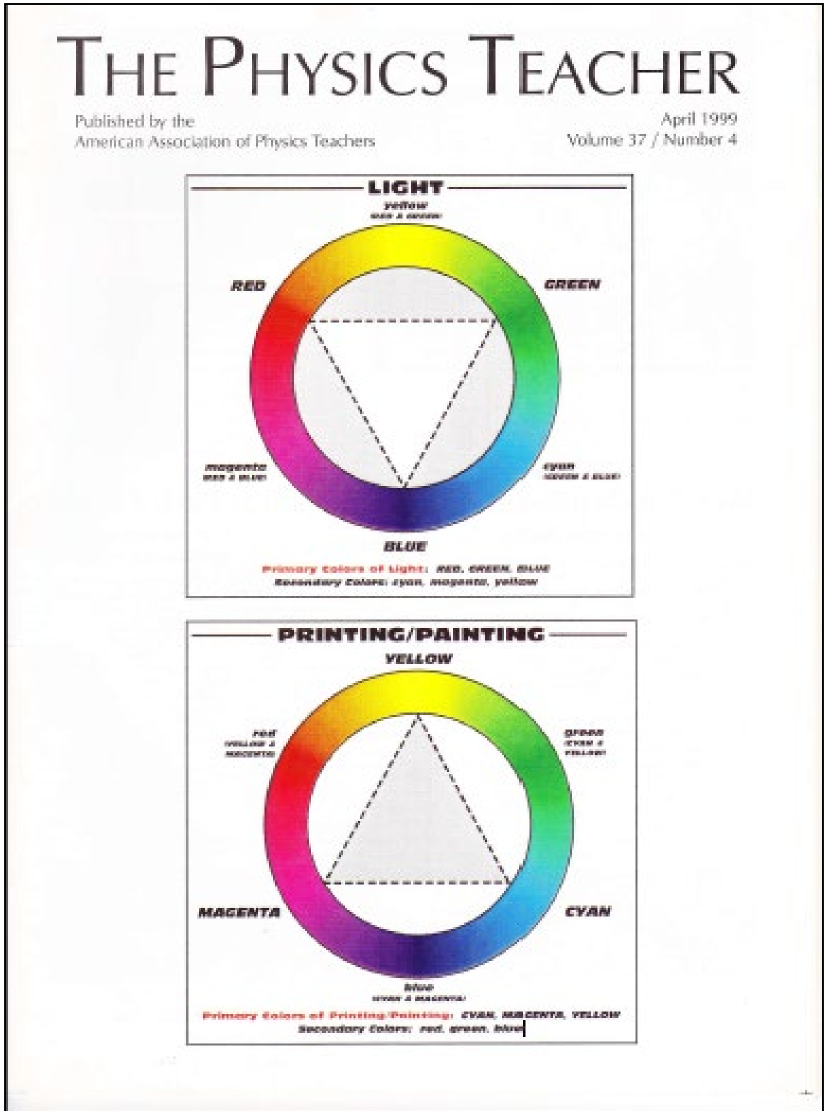
- *Black is the result of superimposing the three primary colors: yellow, red, and blue.*
- *Mixing yellow and red together produces vermilion.*
- *Red plus blue gives us violet.*
- *By combining blue with yellow we get green.*



Barron's Art Handbooks: Mixing Colors 1. Watercolor



Publicity for the correct color wheels …



THE PHYSICS TEACHER

Published by the
American Association of Physics Teachers

April 1999
Volume 37 / Number 4

LIGHT

yellow

RED

GREEN

magenta

cyan

BLUE

Primary Colors of Light: RED, GREEN, BLUE
Secondary Colors: cyan, magenta, yellow

PRINTING/PAINTING

YELLOW

red

green

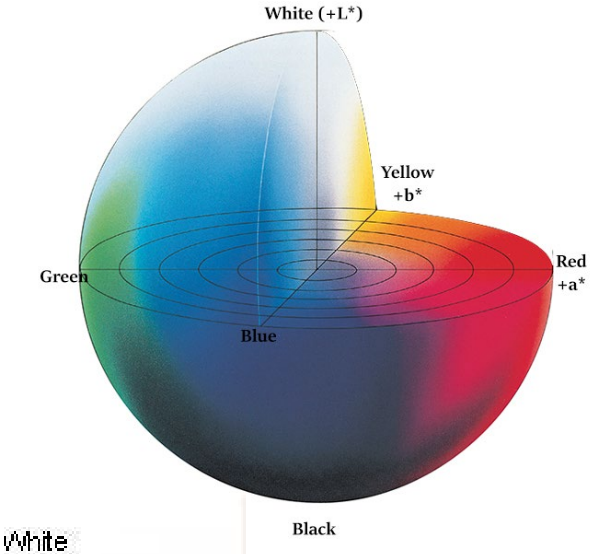
MAGENTA

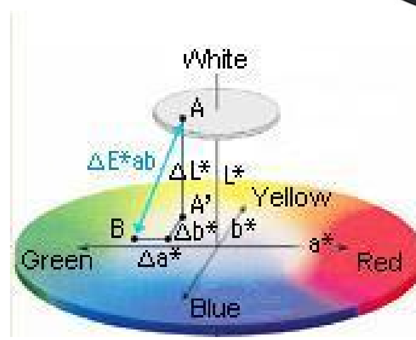
CYAN

blue

Primary Colors of Printing/Painting: CYAN, MAGENTA, YELLOW
Secondary Colors: red, green, blue

Education informs industrial work!





SCIENCES EDUCATION FOUNDATION
GENERAL ATOMICS

Still … Water misconceptions … by experts!

A professor of oceanography documented 110 misconceptions about the oceans held by his students who were not science majors. In this article, we've focused on a smaller number of misconceptions that might be held by elementary students. In addition, we've included ideas for formative assessment and suggestions for teaching correct scientific concepts and principles.

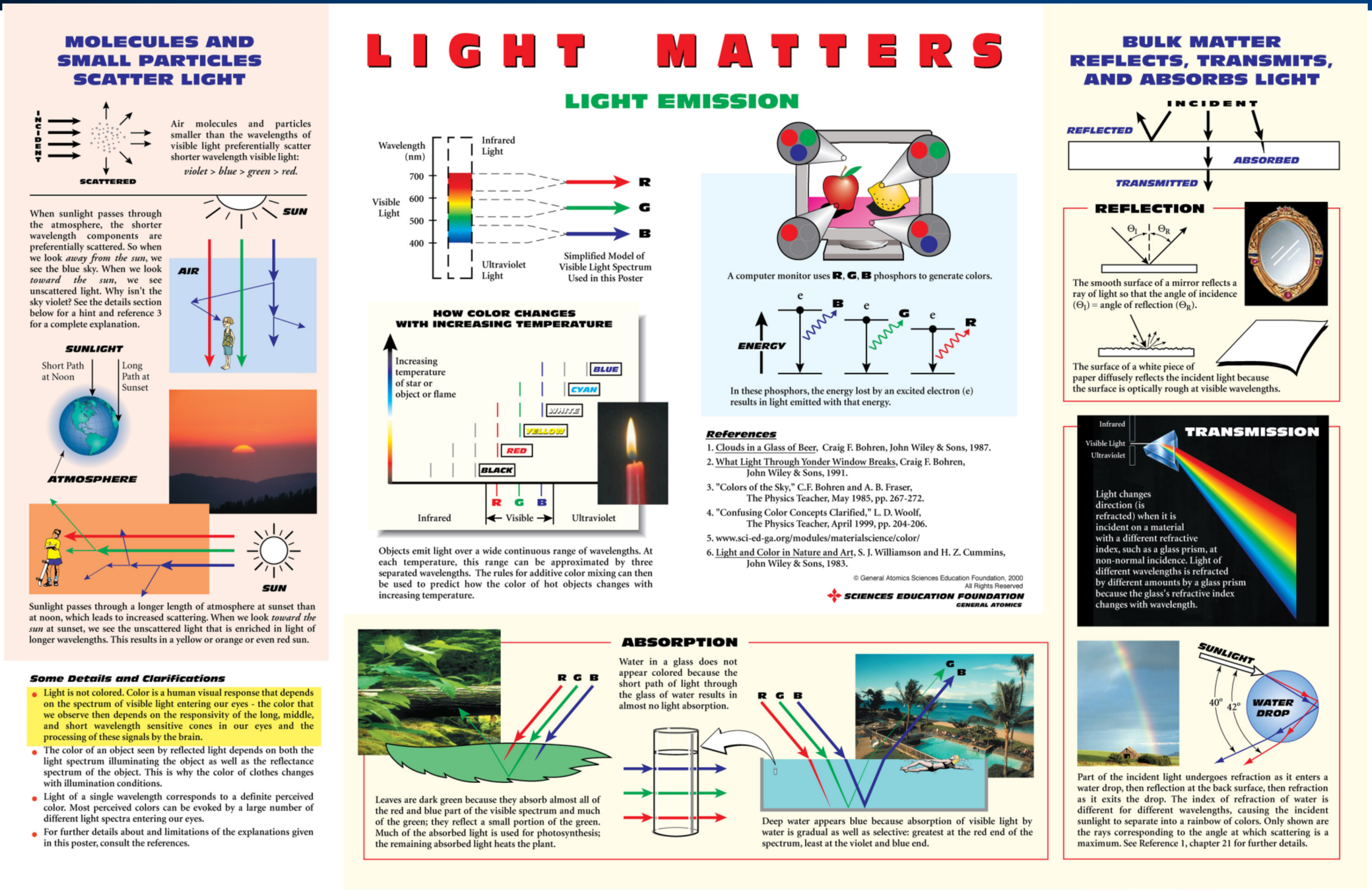
MISCONCEPTIONS

Ocean Characteristics

STUDENTS MAY THINK...	INSTEAD OF THINKING...
Oceans are shaped like a bowl.	While the continental shelf and continental slope may remind students of a bowl, the ocean floor is not flat, nor is it uniform. Canyons, mountains, and plains are all found on the sea floor.
Oceans are deepest in the middle.	Many of the oceans' deepest points are trenches, deep canyons that are formed at plate boundaries. These are not in the middle of oceans.
The sea floor is flat.	The sea floor has canyons, mountains and mountain ranges, and plains just as the land does. Many of these features are much larger than those found on land.
The bottom of the ocean is a big, sandy desert.	The ocean floor is rocky and uneven.
Coasts and coastlines do not change.	Coasts and coastlines change as a result of erosion. Sea-level rise may also affect them.
The ocean is blue because it reflects the color of the sky.	Sunlight is made up of all colors of the rainbow. When sunlight hits the ocean it is scattered by the water molecules. Blue light is scattered the most – which is why the ocean looks blue. However, floating plants, sediments, and algae may make the ocean appear to be green, yellow, or even red!

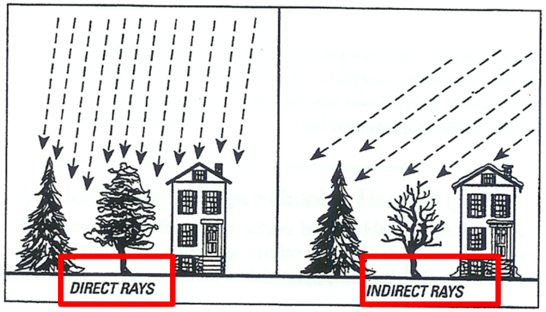
https://beyondpenguins.ehe.osu.edu/issue/polar-oceans/common-misconceptions-about-oceans#misconceptions

Blue water confusion: Light Matters Poster



SCIENCES EDUCATION FOUNDATION
GENERAL ATOMICS

Misconceptions about seasons

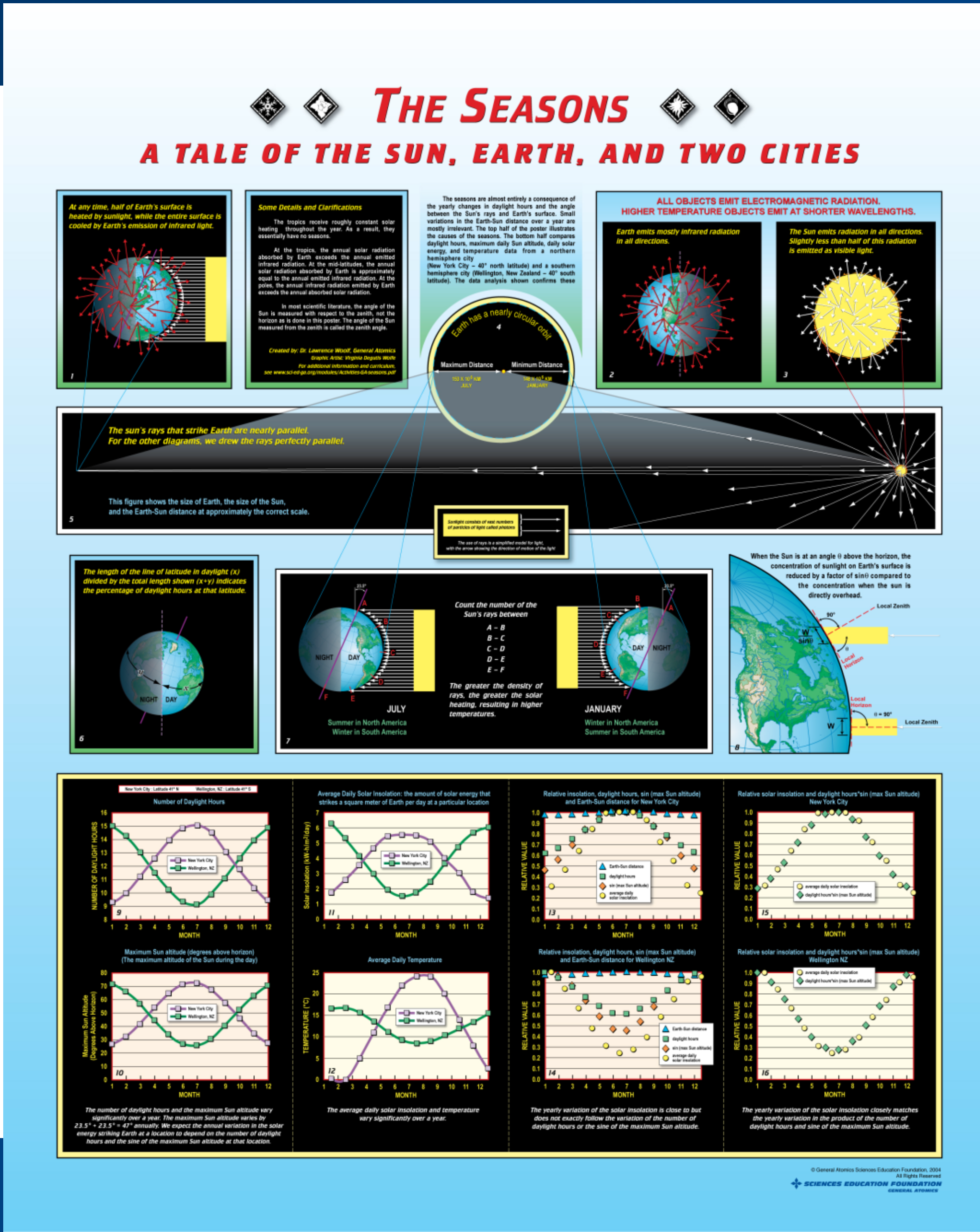


Two factors resulting from the tilt of the Earth's axis account for seasonal weather changes. First, in summer the Sun shines higher in the sky and its rays beat more directly down, warming the surfaces they contact. In the winter when the Sun is lower in the sky, its light reaches the ground at a lower 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



A guest appearance on The Big Bang Theory …

And another

…and another

SCIENCES EDUCATION FOUNDATION
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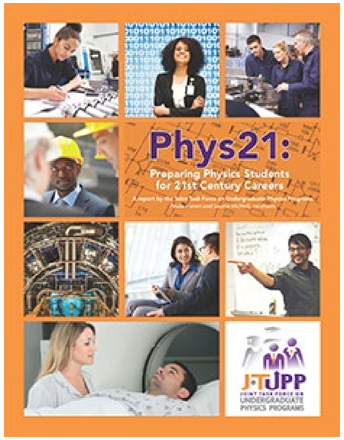
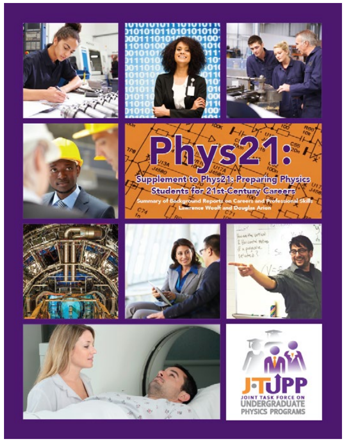
Part 3: APS/AAPT Joint Task Force on Undergraduate Physics Programs

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



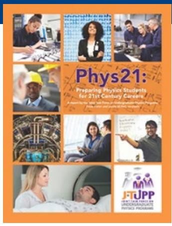


Recall 8 when I discuss the Phys21 Supplement:
Document your work in manner that *is actionable* and can be easily understood by a co-worker a year from now.

compadre.org/phys21

Some slides include text from Laurie McNeil's talk at the 2017 APS March Meeting

J-TUPP MEMBERSHIP

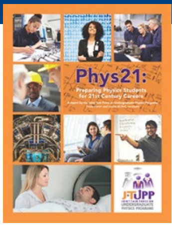


Paula Heron, co-chair, *University of Washington*
Laurie McNeil, co-chair, *University of North Carolina, Chapel Hill*

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*

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

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

Physics Career Paths

Career Options for Physicists

ATTENTION PHYSICS STUDENTS:

You Have Options

Q: What can you do with a physics degree?

A: Get a PhD and become a physics professor OR ...

What comes after the "or" is not widely known in many physics departments, even though data show that only about a third of physics bachelor's degree recipients enroll in a physics or astronomy graduate program within one year of graduating. People with undergraduate degrees in physics pursue a variety of fascinating, fulfilling, and well-paying careers. This is evidenced by decades of data collected by the Statistics Research Center at the American Institute of Physics. Illustrated below are the common paths of physics bachelor's recipients based on the most recent data. Unless otherwise indicated, all data are for graduates of US physics programs who remain in the United States.

Over 7,300 physics bachelor's degrees were awarded in the class of 2012–13.

A record high![1] Typically...

- Three-fourths of those who earn physics bachelor's degrees have **research experience**.[2]
- One-third graduate with a **double major**, many in math.[3]
- One-tenth start at **two-year colleges**.[4]

Within one year of earning a physics bachelor's degree...

~22% enroll in professional degree programs or attend graduate school NOT in physics or astronomy.[5]

- About half enter an **engineering** program; the rest enter programs in math, medicine, education, or another field.[5]
- As a group, physics majors score among the highest of all majors on medical school and law school admission tests (the **MCAT** and **LSAT**).[6]
- Students in professional degree programs are more likely to be **self-funded** than students in research-based graduate programs, who usually have teaching assistantships, research assistantships, or fellowships.[5]

~36% attend graduate school in physics or astronomy.[5]

- About 80% enroll in a **PhD program**; the remainder choose a master's degree program.*
- Most are **fully supported** by teaching assistantships, research assistantships, or fellowships.

Of those who start graduate school in physics or astronomy...

~42% enter the workforce.[5]

Common employment sectors include:

Private sector[7]

- Typically, **half** of those who enter the workforce take jobs in the private sector.
- Of those that enter the private sector, the majority hold science, technology, engineering, and math **(STEM) positions**.
- Those in private-sector STEM positions are well compensated, with a median starting salary of about **$50K**.

Colleges or universities[7]

- More than half of the students in these positions initially work at the same institution they graduated from. Many work in research or IT.

Civilian government[7]

- The civilian government sector includes national labs. The vast majority of these positions are in STEM fields, many related to defense or energy.

Active military[7]

- Physics bachelor's work across all branches of the armed forces. Many work in aviation or nuclear power.

High school teaching[7]

The Statistical Research Center does not formally follow the career paths of these individuals, but we hear that they go on to successful careers in engineering, management, education, law, medicine, business, and a variety of other areas.

Add to the mix:

Foreign citizens coming to the United States for a graduate degree, students who earned bachelor's degrees in another field but want a graduate degree in physics, and students who earned a physics bachelor's degree in previous academic years.

~1 out of 6 US physics bachelor's receive a physics or astronomy PhD.*

- A doctorate in physics takes an average of **6–7 years**.[10]
- Most PhD students are **fully supported** by teaching or research assistantships or fellowships.

Within one year of earning a physics PhD...

~1 out of 12 US physics bachelor's receive an exiting physics or astronomy master's degree.*

Exiting master's degree recipients are individuals who leave their current department upon receiving a master's degree. Many other students earn an en route master's degree, continuing on to a physics PhD in the same department.

- About two-thirds of those who earn exiting master's degrees do so with a **specific research focus**.[8]
- A master's degree in physics usually takes about **two years**.

For US citizens, within one year of earning an exiting master's degree...

~2/3 enter the workforce.[9]

- About half work in the **private sector**, overwhelmingly in STEM fields.
- The largest portion of exiting master's working in the private sector are employed in the field of engineering.
- Other common employment sectors for exiting master's include **colleges and universities, high schools, civilian government, and the military**.

~1/3 continue with graduate studies.[9]

- Some transfer to other institutions to earn a **physics PhD**.
- Many others transfer to programs in **related fields** such as medical physics, atmospheric science, and materials science.

~2/3 accept a temporary position

(e.g. a postdoc), primarily at a university or with the government.[11]

~1/3 accept a potentially permanent position.[11]

- The majority of new PhDs accepting potentially permanent positions are employed in the **private sector**.
- The **highest-paid** positions for new PhDs are in the private sector and at government labs, with median starting salaries of about **$90K and $85K**, respectively.

The approximate breakdown by employment sector for all employed physics PhDs

(not just new ones), is given below.*

- 45–49% Private sector
- 29–33% Academe
- 14–17% Government
- 5–7% Other

References and Notes

The following reports were published by the Statistical Research Center of the American Institute of Physics and are available online at: www.aip.org/statistics.

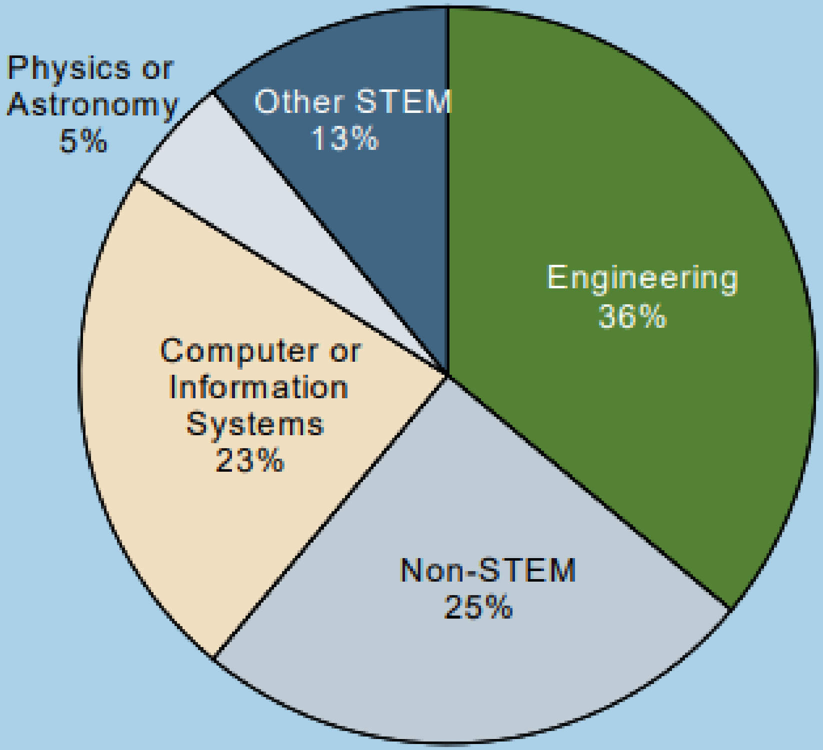
1. Starr Nicholson and Patrick J. Mulvey, *Roster of Physics Departments with Enrollment and Degree Data, 2013*, August 2014.
2. AIP Statistical Research Center, *AIP Physics Trends: Research Experiences of Physics Undergraduates*, Fall 2009.
3. AIP Statistical Research Center, *AIP Physics Trends: Physics Students Have Broad Interests*, Spring 2011.
4. Susan White and Raymound Chu, *Physics Enrollments in Two-Year Colleges*, April 2013.
5. Casey Langer Tesfaye and Patrick Mulvey, *Physics Bachelor's One Year After Degree*, September 2014.
6. Casey Langer Tesfaye and Patrick Mulvey, *MCAT, LSAT and Physics Bachelor's*, December 2013.
7. Casey Langer Tesfaye and Patrick Mulvey, *Physics Bachelor's Initial Employment*, September 2012.
8. Patrick J. Mulvey and Starr Nicholson, *Trends in Exiting Physics Master's*, March 2014.
9. Patrick Mulvey and Brandon Shindel, *Physics & Astronomy Master's Initial Employment*, April 2011.
10. Patrick J. Mulvey and Starr Nicholson, *Trends in Physics PhDs*, February 2014.
11. Garrett Anderson and Patrick Mulvey, *Physics Doctorates Initial Employment*, July 2012.

*Estimate provided by the AIP Statistical Research Center, Summer 2014.

Learn more at the Careers Toolbox website:

www.spsnational.org/careerstoolbox

Field of Employment for Physics Bachelors in the Private Sector, Classes of 2013 & 2014 Combined



STEM refers to natural science, technology, engineering, and mathematics.

Figure is based on 1,141 responses

www.aip.org/statistics

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

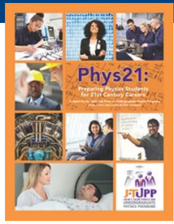
- High School Physics Teacher
- High School Science Teacher
- Middle School Science Teacher

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

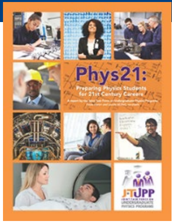


To better prepare students for diverse careers does *not* mean abandoning the rigorous technical education that makes a physicist a physicist, nor does it mean regarding your program as providing only vocational training.

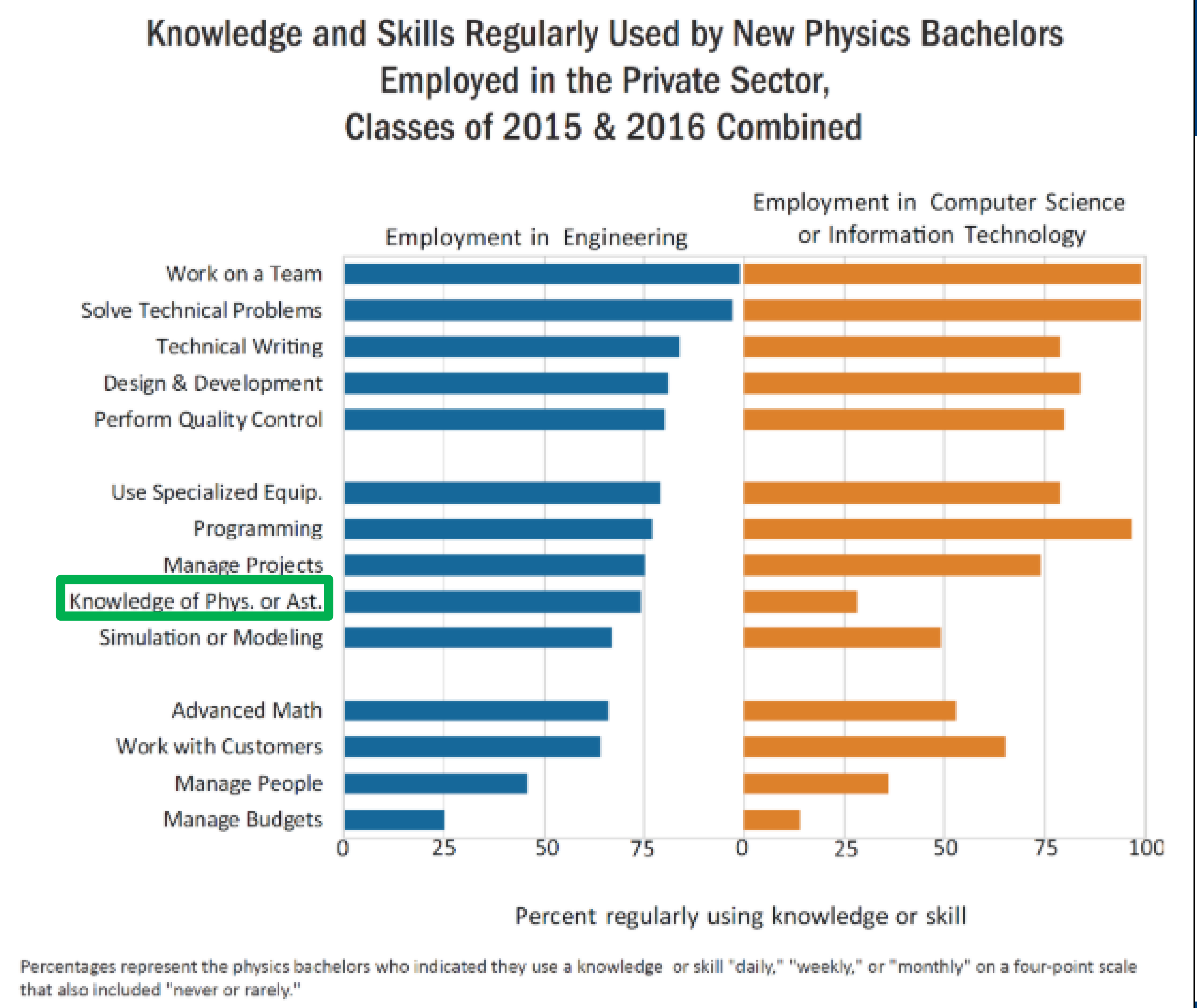
It *does* mean evaluating whether your department is doing its best to prepare students to compete with graduates in other fields (such as engineering) for desirable employment and career options.

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

WHAT DO EMPLOYERS WANT?

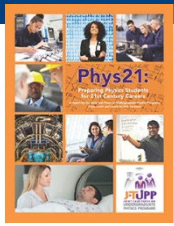


1. The ability to work well in teams—especially with people different from oneself
2. An understanding of science and technology and how they are used in real-world settings
3. The ability to write and speak well
4. The ability to think clearly about complex problems
5. The ability to analyze a problem 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



SCIENCES EDUCATION FOUNDATION
GENERAL ATOMICS

LEARNING GOALS FOR PHYSICS PROGRAMS



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

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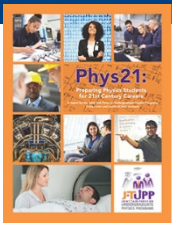
LEARNING GOALS FOR PHYSICS PROGRAMS cont.



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

Boeing List of "Desired Attributes of an Engineer"

- A good understanding of engineering science fundamentals
  - Mathematics (including statistics)
  - Physical and life sciences
  - Information technology (far more than "computer literacy")
- A good understanding of design and manufacturing processes (i.e. understands engineering)
- A multi-disciplinary, systems perspective
- A basic understanding of the context in which engineering is practiced
  - Economics (including business practice)
  - History
  - The environment
  - Customer and societal needs
- Good communication skills
  - Written
  - Oral
  - Graphic
  - Listening
- High ethical standards
- An ability to think both critically and creatively - independently and cooperatively
- Flexibility. The ability and self-confidence to adapt to rapid or major change
- Curiosity and a desire to learn for life
- A profound understanding of the importance of teamwork.

> - *This is a list, begun in 1994, of basic durable attributes into which can be mapped specific skills reflecting the diversity of the overall engineering environment in which we in professional practice operate.*
> - *This current version of the list can be viewed on the Boeing web site as a basic message to those seeking advice from the company on the topic. Its contents are also included for the most part in ABET EC 2000.*

https://ocw.mit.edu/courses/mechanical-engineering/2-000-how-and-why-machines-work-spring-2002/lecture-notes/lecture3MEoverview_fixed.pdf

Resources

- Phys21 Report and Supplement
  - https://www.compadre.org/JTUPP/
- Physics Today article on Phys21
  - https://physicstoday.scitation.org/doi/10.1063/PT.3.3763
- APS News Backpage article on Phys21
  - https://www.aps.org/publications/apsnews/201702/backpage.cfm
- AIP Career Pathways Project
  - https://www.spsnational.org/career-resources/career-pathways
- APS Physics Career Guidebook
  - https://www.aps.org/careers/guidebook/index.cfm

Thank You!