Diverse Engineering: Real Examples

Diversity In Curriculum

Diversity in Science & Engineering starts with diversity in the educational background & work experience of the personnel who are addressing the problem. For example, I have a (ref [1]):

- Bachelor of Science (BS), Mechanical Engineering, Georgia Tech (GT) (1982)
- Masters of Science (MS), Physics. Virginia Tech (VT off campus) (1987)

Through my continuing education, an Off-Campus Graduate Physics program did not require a Graduate Record Examination (GRE) for acceptance in getting an MS in Physics. On the other hand, an Off-Campus Computer Science Program I was contemplating did require a GRE. In the 1980's, the desktop computer had just been introduced the previous decade. If the Physics MS degree had required a GRE, I may have put in the extra effort & taken the GRE for the Computer Science degree. I have since been advised to get a degree in a field that applies computers, but not to specialize in computer programming. I have heard examples of pure Computer Science jobs being shipped to low-infrastructure countries like India.

Bring in the Engineers

An educational institution can produce carbon copy Physics or Engineering graduates from the same mold by requiring GREs, but as this report will show, the cross-education of different fields of Engineering & Physics is what moves the Science forward with more creative solutions.

The four major fields of Engineering based in Physics are:

- Aerospace Engineering (AE)
- Civil Engineering (CE)
- Electrical Engineering (EE)
- Mechanical Engineering (ME)

In a general educational curriculum, the above degrees follow an initial first 2-years of Physics & Calculus introduction in course work. Fortunately, the MS Physics program I attended was structured well enough, that learning MS Physics began where my 2 years of undergraduate Physics (using ref [3]) deviated into Engineering specialization.

For full disclosure, I eventually took the Physics GRE after obtaining an MS in Physics & obtained a Physics score of 60% (I scored in the Physics portion of the exam better than 60% of the entire United States (US) taking that exam offering.) I did not have a BS in Physics & still am deficient in some areas like atomic theory.

Cross-Application Physics

It is my hope that graduate Physics Programs can still accept AE, CE, EE, ME majors into off-campus MS Physics without a GRE. From the cross-application of Engineering & Physics disciplines, I produced some significant but unusual applications of Engineering modeling applied to Physics:

- **Blockage Diagrams:** Developed spherical-polar plots (blockage diagrams) of 3D ship topside models, independently. My version of blockage diagram development was directly derived from the discussion & graphics of spherical polar plots given in Arfken (refs [1] & [2] & [6]).
- **Space Travel Modeling:** Simulated travel of interstellar spaceships near the speed of light using Runge-Kutta. Flight path modeling of ship-launched missiles is fundamental to a safe shipboard launch. I supported documentation of this data in my Computer-Aided-Design (CAD) work. I later investigated spaceship travel near light speed using Runge-Kutta integration of ordinary differential equations expressed in Special Relativity (refs [7] & [11] & [12]).
- **Optical Filter Functions:** Proposed rendering of star scenes near the speed of light using the human eye filter functions. As I modeled spaceship travel, I conjectured what the view would be out a window of the space craft near light speed. My speculation was partly based on the Star Trek media franchise including its original (1966 – 1968) 3D star field traversal (ref [4]). A star's spectral signature can be approximated across many wavelengths. Then, the graphic rendering from the Doppler shift of star light, nebulae or any object can be estimated using eye-RGB filter functions (ref [5]).

The fields of Physics & Math are vast; even PhD's cannot bring all of this knowledge to solve problems. Engineering disciplines under Physics collect tools of their specialized degrees to solve unique problems of their own. That's why when Engineers are allowed into MS Physics, unique applications of theory answer questions like: "What shade of blue is that Doppler shift during space travel?" These solutions do not warrant publication, but they do solve problems that allow Physics to be used in different ways.

I realize that AE's & CE's may be deficient in analog electromagnetism (EM). As luck would have it, I learned Arfken's vector Calculus before Jackson's introduction to EM through Maxwell's Equations (refs [6] & [8]). However, put a CE or AE through standard MS Physics texts of Arfken / Jackson / Goldstein / Merzbacher (or similar textbooks, see refs [6] / [7] / [8] / [9]), some Physics problems may be solved which have heretofore been skipped over & by-passed by Physicists interested in the more general picture. Adding a course in numerical analysis, I have gotten a lot of mileage from the above textbooks.

BTW, Runge-Kutta Methods (pronounced RUUNG-a KUUT-tah) use numerical computation techniques to approximate a solution to an ordinary differential equation based on known conditions @ one independent point. These techniques are limited to arithmetic operations & let computer calculations approximate equation solutions @ another independent point. The technique predates the computer age & was developed by two Germans, Carl Runge (1856 – 1927) & Wilhelm Kutta (1867 – 1944), around 1900 (refs [10] & [11]).

Examples: Engineers Outside Engineering

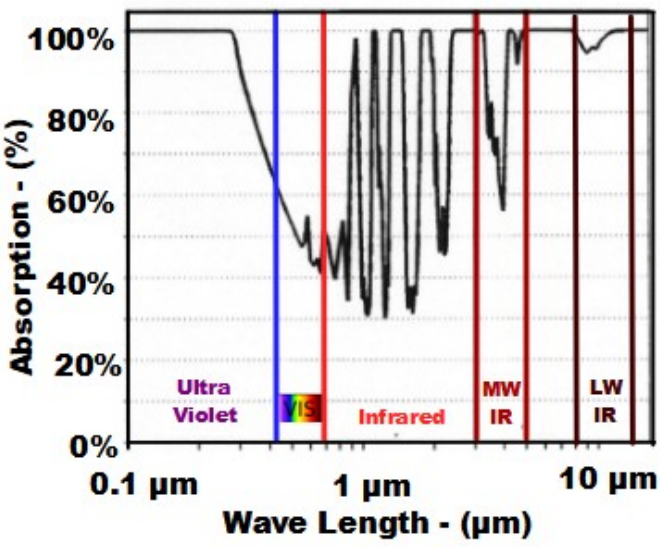
Sometimes, Pure Physicists are asked to solve engineering problems that aren't Pure Physics research, but nevertheless need an understanding of Physics. Part of my Engineering work history involved supporting infrared (IR) sensors for the US Navy. The design & support of optical sensors such as IR sensors can loosely be grouped under the field of Optical Engineering.

Visible & IR Windows

color	range	wavelength (μm)	wavelength (nm)	frequency (THz)	Temperature (K)	Temperature (°F)/(°C)
blue	lo	0.38	380	789		
yellow	mid	0.58	580	517	5700 K	9800° F
red	hi	0.75	750	789		5400° C
near infrared	lo	3.0	3000	100	770 K	930° F
	hi	5.0	5000	60		500° C
far infrared	lo	8.0	8000	38	280 K	50° F
	hi	14.0	14000	21		10° C

Optical Engineering: There just aren't enough jobs in society to warrant a full Optical Engineering major in college. The unit I worked with, threw MEs, EEs & Physicists into a group. We had to make an effort to learn the field when we got there, e.g., spectral signatures, filter functions, extinction coefficients. Science may ask "What shade of blue is the Doppler shift on that object due to space travel?" Wait for the Optical Engineer, who can approximate the answer good enough! Or a Physicist can re-invent Optical Engineering.

In the cross-application of optical engineering, I was asked to determine the feasibility of using infrared (IR) sensors underwater for the US Navy. The light we see has a wavelength range of about 0.38 μm (**blue**) to 0.75 μm (**red**) centered on 0.58 μm (**yellow**) (ref [13]). For our Darwinian Earth, we have a significant atmospheric transmission window for our visibility range. The Sun's (effective) surface temperature (about 9930°F or 5500°C, refs [14] & [15]) has a Darwinian peak radiation @ **yellow** of about 0.58 μm, also.

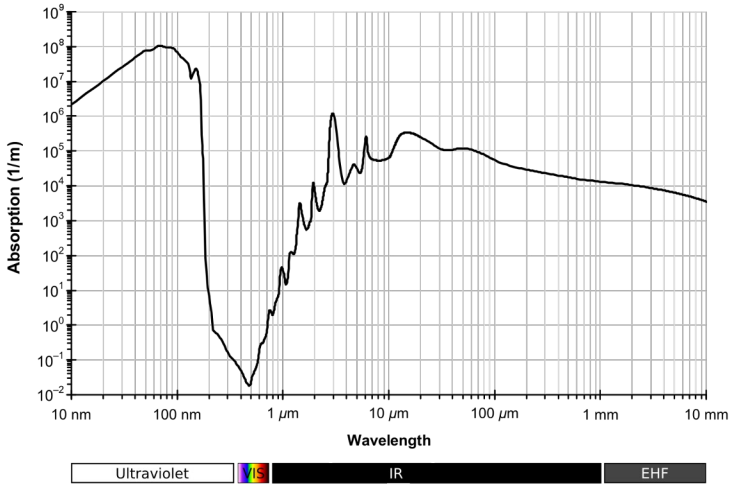


Typical Terrestrial Atmospheric Absorption

IR windows are given various names in the industry. Per ref [16], an atmospheric Mid Wave IR (**MWIR**) window is @ about 3 to 5 μm. An atmospheric window for Long Wave IR (**LWIR**) sensors is @ about 8 to 14 μm. Typical absorption for the **MWIR** & **LWIR** windows of Earth's atmosphere are shown in the above graph along with the visible window (ref [17]). Spectral absorption values across these windows are extremely dynamic going from near 100% in a fog & decreasing. Likewise for Earth-based IR sensors, the technologies required to support these windows vary.

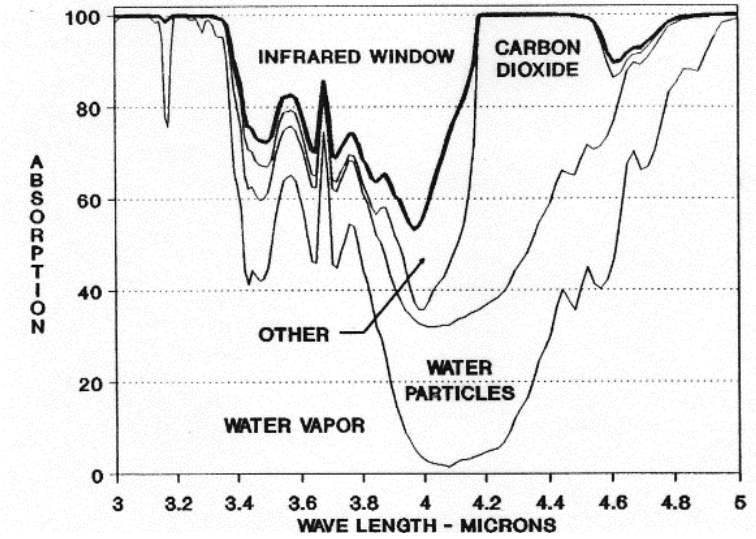
As the world adds even more "not so" Darwinian carbon dioxide (CO_2) & other greenhouse gases to the atmosphere, the above graph would show a further approach

to 100% absorption in the above windows. The surface temperature of Venus is over 800°F or 400°C, primarily because the 96.5% atmospheric CO_2 (ref [18]) has closed the Venusian absorption window almost completely.



Liquid Water Spectral Absorption

Underwater Optics: Visible light travels relatively far in clear water. This led my boss to conjecture some promise for IR sensors in water. Unfortunately, references (ref [19]) indicated opaqueness increases to the extent that light is readily absorbed in "clear" water in IR ranges (see above graph). I added further proof & indicated for microwave ovens at longer wavelengths, water is opaque to their radiation, also. The standard microwave oven radiates at about 12 cm (5 inches) wavelength (ref [20]). Observing that when water absorbs radiation, it also heats up, is an application of Thermodynamics' 1st Law, Conservation of Energy. The energy used to produce the light equals the energy absorbed by the water.



Mid Wave IR Terrestrial Atmospheric Absorption

The terrestrial atmospheric **MWIR** window (3 to 5 μm) is shown in the graph to the left, along with typical gas contributions (ref [17]). For both "clear" water & the Venusian atmosphere, the data indicates the **MWIR** window would be @ about 100% absorption across the graph window. The software generating this terrestrial atmospheric absorption data is the results of the much-appreciated work of atmospheric modelers.

A Place for Women & Minorities

The Physics schools of higher learning & the resultant professions are deficient in women & minorities. From the above examples with Engineers, the more varied the education, culture & experiences that the student has, the more likely solutions are proposed for intractable problems. Of course, this is not the first time "Diversity" has been preached in the work place.

Women were excluded from the history of Physics because, until we had birth control &

infant formula, they were chained to the kids they had. Now we have 7Gig people in the world; having a kid isn't that important; women don't really have to take care of their kids after an initial period; women are free to pursue a degree in Physics. That's why there are ***not*** many older generation of women in the Physics text books.

Cultural Diversity

This article has given examples of educational diversity that paid-off in modest ways. Can Cultural Diversity also give benefits? The island nation of Japan can serve as an anecdotal (get it right eventually) example adopting western technology & knowledge. In 1854, the US sent Commodore Matthew C. Perry to force the opening of Japan to the outside world (ref [21]). Japan isolationism was abandoned, opening its markets to the US entrepreneurs & that of other nations. Japan began pragmatically adopting all available technologies that it could implement successfully. The resource-poor archipelago rapidly industrialized, unfortunately concentrating on its samurai warrior past.

Once it adequately modernized within 4 decades, Japan began attacking its neighbors. In 1894, the superior Japanese military attacked its regional historic foe, neighboring China, taking away the Korean peninsula (ref [22]). This warfare continued in 1941 with Japan's bombing of Pearl Harbor. In 1945, to avoid a costly Allied amphibious invasion, the US military dropped (ultra-modern) atomic bombs on Hiroshima & Nagasaki (ref [23]) obtaining unconditional Japanese surrender. Insights through feedback may have helped better mold the path that modernization of Japan took (refs [24] & [25]). However, if not the US, then who? Mid 19th century Japanese isolationism was "ripe" for investment by some "western" benefactor on a sliding scale from greedy exploitation to altruistic industrialization.

After World War II in a peacetime setting, Japanese Science Research has assumed the same stature as other cultures. Japanese born Shin'ichirō Tomonaga (1906 – 1979) (ref [26]) along with Americans Richard Feynman (1918 – 1988) (ref [27]) & Julian Schwinger (1918 – 1994) (ref [28]) jointly won the 1965 Nobel Prize in Physics for their contributions to Quantum Electrodynamics (QED). In addition, Japanese Engineering contributions currently excel in the areas of earthquake & tsunami mitigation. Japanese are experts on implementing building codes & tsunami warning systems in surviving these natural disasters (ref [29]).

Dead White Nerds

Last time I looked at the Institute of Physics (IOP) website (ref [30]), they were pushing Physics for women in the United Kingdom. That's exactly what colleges need to do in the US! The easiest way to find a date is to talk to the person sitting next to you in Physics class. That's how I found my near-perfect wife. No online dating was needed. I blame external factors for breaking up my marriage. I met my physicist-wife in Physics

class. Men / Women introverts gravitate toward Physics: Physics homework gives physics-introverts something to talk about. Unfortunately, Orville (1871 – 1948) & Wilbur Wright (1867 – 1912) (ref [31]), Isaac Newton (1643 – 1727) (ref [32]) & Nikola Tesla (1856 – 1943) (ref [33]) all died unmarried having lived stoic but very productive lives!

Even through MS Physics, one is studying contributions of dead-white-men. I'm sorry; the names of dead-white-male-physicists are attached to many physical concepts, laws & constants. Women & minorities will just have to put up with that. Unfortunately, one key to me getting motivated to study the material is that these folks were given a problem & this is what they did to solve it. The student has to recognize the “spark” that solved a significant problem in the past to solve new problems in the future! There is a rainbow of contributors in professional Physics now in NASA, JPL, CERN & elsewhere that can serve as role models. Unfortunately, one has to study a lot of dead-white-men, first.


CA de Coulomb
1736 – 1806

Shadow of Calculus: Calculus is a branch of math invented by a Physicist for Physics. Math is a vast field, unfortunately many of today’s problems are solved using Calculus. Engineers for the most part are all living in Newton's shadow. Isaac Newton solved the motion of planets around a central force proportional to the inverse square of the distance (refs [34] & [35]). Charles-Augistin de Coulomb (refs [36] & [37]) measured EM force between electrified bodies with repulsive & attractive forces, following “the inverse proportion of the square of the distance." Coulomb was re-applying Newton to electricity with an inverse square law. Of course, there's electrical current, magnetism & other factors in describing EM. Michael Faraday (1791 – 1867) (ref [38]), James Maxwell (1831 – 1879) (refs [39] & [40]), Hendrik Lorentz (1853 – 1928*)* (ref [41]) & others kept investigating, riding a horse & buggy to their laboratories; doing their experiments by candlelight, until we have the EM knowledge we have now. However, it’s mostly a repeat of Newton (refs [32] / [36] / [38] / [39]).

Unfortunately, all of these scientists are dead-white-men, but minorities & women don't have to let that get to them. The intractable problems we have ***now*** are the ones that can't seem to be solved by white-European-men, e.g., the double slit experiment, onset of flat-plate turbulence, to name a couple.

Contributing to Physics Without PhD Credentials

If the under-advantaged student wants to make significant contributions to Physics, then two quotes should be remembered:

> ”Now, for something completely different.”
>
> --- Monty Python’s Flying Circus

> “If they said I couldn't do it because I was black, I set about to prove them wrong.”
>
> --- Gen. Colin Powell (unknown TV show)

The underprivileged students should not try to compete with the Physics "Professionals" who image the black hole at the center of our galaxy (ref [42]). By orders of magnitude,

these Physicists carry on the work of the first Physicist, Galileo (1564 – 1642) & his hand-made telescopes (ref [43]). By using 4-vectors, they cover Special Relativity (SR) (ref [44]) emphasizing General Relativity (GR), the all-encompassing contribution of Einstein (1879 – 1955) (ref [45]) be rendered from the spaceship moving near light speed. I also outlined how to estimate Doppler shift color near the speed of light. For the Optical Engineer, it's simply a direct brute force method with no elegance, but one outside the usual scope of standard Engineering & Science.

Contributions like mine are small cogs in a much bigger machine that hopefully will continue. The Science / Technology / Engineering / Mathematics (STEM) college graduate should strive to contributed incremental improvements to Science & Engineering so others can advance his / her ideas further. I'm a small player in a collection of people trying to improve US Navy weapon zones. I'm just a cog in the Star Trek folks trying to create something that we & our descendants can look forward to.

References

[1] George, Everett, *Idea Contributions*, Transcripts - E.George 2023.
[2] George, Everett, *Naval Engineers Journal*, Weapon Firing Zone Design, May 1991.
[3] Halliday, David, et al, *Principles of Physics*, 11th Ed, Wiley, 2020.
[4] Wikipedia.org, Star Trek, 2023.
[5] George, Everett, *Interstellar Space Travel Simulation,* SRProposal.pdf, 2022.
[6] Arfken, GB, PhD, et al, *Mathematical Method for Physicists*, 7th Ed, Elsevier, 2012.
[7] Goldstein, Herbert, PhD, et al, *Classical Mechanics*, 3rd Ed, Addison-Wesley, 2011.
[8] Jackson, John David, PhD, *Classical Electrodynamics*, 3rd Ed, Wiley, 1998.
[9] Merzbacher, Eugen, PhD, *Quantum Mechanics*, 3rd Ed, Wiley; 2011.
[10] Wikipedia.org, Runga–Kutta Methods, 2023.
[11] Press, WH, PhD, et al, *Numerical Recipes*, 3rd Ed, Cambridge U Press, 2007.
[12] French, AP, PhD, *Special Relativity*, 1st Ed, MIT Physics, WW Norton & Co, 1968.
[13] Helmenstein, AM, PhD, ThoughtCo, Understand the Visible Spectrum, 2020.
[14] Wikipedia.org, Effective Temperature, 2023.
[15] Rapid Tables, Online Comprehensive Units Conversion Calculator
[16] Xenics Photonis Group, Infrared Radiation Technologies, 2023.
[17] Kneizys, FX, et al, *User's Guide to LOWTRAN 7*, USAF Technical Report AFGL-TR-88-0177, 16 August 1988.
[18] Wikipedia.org, Venus, 2022.
[19] Wikipedia.org, Electromagnetic absorption by water, 2022.
[20] Volmer, Michael, Food Physics, IOP.org, Physics of the Microwave Oven, 2004.
[21] Wikipedia.org, Japan, 2024.
[22] Wikipedia.org, 1st Sino-Japanese War, 2024.
[23] Atomic Archive, Mushroom Cloud over Nagasaki, 2022.
[24] FacingHistory.com, Japanese Imperialism & the Road to War, 2024.
[25] American Historical Association, Japan & Future Aggression, 2024.
[26] Wikipedia.org, Shin'ichirō Tomonaga, 2024.
[27] Wikipedia.org, Richard Feynman, 2024.
[28] Wikipedia.org, Julian Schwinger, 2024.
[29] Japan Foreign Affairs, Disaster & Disaster Prevention, 2024.
[30] Institute of Physics, IOP.org, 2022.

[31] Wikipedia.org, the Wright Brothers, 2023.
[32] Wikipedia.org, Isaac Newton, 2023.
[33] Wikipedia.org, Nikola Tesla, 2023.
[34] Hewitt, Paul G, *Conceptual Physics*, 12th Ed, Pearson Press, 2014.
[35] George, Everett, *Idea Contributions*, Calculus Elucidates Kepler's Laws, 2024.
[36] Wikipedia.org, Charles-Augustin de Coulomb, 2022.
[37] Alamy.com, Portrait – CA Coulomb, Image ID: HKCK0E, 2024.
[38] Wikipedia.org, Michael Faraday, 2022.
[39] Wikipedia.org, James Clerk Maxwell, 2022.
[40] George, Everett, *Idea Contributions*, Maxwell's Equations Demystified, 2024.
[41] Wikipedia.org, Hendrik Lorentz, 2024.
[42] Castelvecchi, David, Black Hole Imaged for 1st Time, Nature, 2022.
[43] Wikipedia.org, Galileo Galilei, 2022.
[44] George, Everett, *Idea Contributions*, Why Can't We Exceed Light Speed?, 2024.
[45] Wikipedia.org, Albert Einstein, 2022.

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