concepts, such as modular tensor categories, manifest themselves in the current–voltage measurements of two-dimensional transistors? Yet they do in quantum Hall effects, and they continue to be relevant in the emerging subject of topological materials and phenomena now dominating condensed-matter physics.

Similarly, the Dirac equation turned out to be the right description for electrons and positrons in vacuum, but the almost equally beautiful theories of Hermann Weyl and of Ettore Majorana languished in particle physics. Whether neutrinos are Majorana fermions—that is, whether they are their own antiparticle—remains unknown. But more than 80 years after Weyl, condensed-matter researchers are discovering solid-state Weyl materials, which exhibit massless, chiral charged quasiparticles. "Chiral two-dimensional massless Dirac equation" turns out to be an excellent continuum description for graphene. And Majorana particles are central to the concepts of non-abelian anyons and topological quantum computation. (See the article by Nick Read, PHYSICS TODAY, July 2012, page 38, and my article with Michael Freedman and Chetan Nayak, July 2006, page 32.) Microsoft has started a worldwide effort to build a quantum computer that has non-abelian Majorana modes and topological quantum field theories at its core.

Materials physicists, many of whom never heard of Weyl and his equation until recently, are busy publishing experimental papers on the search for chiral anomalies in certain types of semimetals. That is unification at its best, but it has not followed a planned, logical course. It has happened purely through general unifying concepts that are enabling us to connect phenomena that seem completely different on first sight. Newton's spirit of unification is still alive and well, but its scale is no longer as grand as it was in 1687, because physics itself is so much grander now.

Unification still rules physics, from the graduate qualifying exam to the creation of quantum computers. We may not see it in our everyday experience of physics, but when it shows up, we immediately realize it, accept it, and use it.

Sankar Das Sarma
(dassarma@umd.edu)
University of Maryland
College Park

LETTERS

A memoir on project-based learning

A story in the June 2017 issue of PHYSICS TODAY recently caught my eye. An Issues and Events story by Toni Feder (page 28) stated that project-based learning is gaining popularity. I am a retired industrial physicist with my PhD in atomic theory. I'd like to share a related story.

I think it was my junior year, 1966–67, at Colorado State University. I was taking a course on modern physics; the class had two parts. The lecture part was traditional and worth five credits, if memory serves me, and the laboratory part would now be called project-based learning. It was worth two credits.

On the first day of lab class, the professor took us to the basement of the physics wing, unlocked the doors of three rooms, and said, "You may use any materials in this room, the next one, and the one at the end of the hall. You are to design and execute five experiments in modern physics, record the data, and make a report on each. The notebooks and reports will be turned in at the end of the quarter and will determine your grade for the class." He then went back upstairs to his office. He was always available, but few needed to consult him.

We were teamed up into groups of two. In addition to choosing from several "canned" experiments, each group took on at least one original experiment. My partner and I chose to measure the stopping potential of the photoelectron. We found a regulated DC power supply with shielding, a student spectroscope, and a few odds and ends, and we cobbled together a credible experiment. The result was within 20% of the accepted value, a quite good result for the equipment available to us.

That class served me well throughout my career. It taught me to read what others had done, adapt their work, and solve problems with the equipment at hand, and it developed in me a passion for the projects I encountered. I had an exciting career that involved topics from programming a direct-reading spectrograph for analytical chemistry to studying iron aluminides. The work was an equal mix of the theoretical and the experimental and was highly interdisciplinary. For example, one summer I was a student hire at Aerojet General to work on Project NERVA, an effort to develop nuclear propulsion for spacecraft.

Among other things, the project-based lab fostered a can-do attitude in me. I strongly applaud the efforts described in Feder's story.

Jack R. Woodyard
(woodyard@ruraltel.net)
Norton, Kansas

Assumptions about climate change skeptics

In his editorial in the August 2018 issue of PHYSICS TODAY (page 8), Charles Day writes about his interaction with a climate change skeptic. Like all of us, he has made some assumptions. The most troubling of those is that the skeptic has some understanding about the nature of science.

Day writes, "I can point out that the current mean temperature is 1 °C higher now than it was in the 1950s." Were he to make that point and then ask the skeptic what temperature indicates, he would get some insight into how shallow the skeptic's understanding is. If he were to ask the difference between heat and temperature, Day would undoubtedly be even more dismayed.

When giving presentations to teachers and the public, I am careful to make sure the participants understand the difference between temperature and heat. I then emphasize the enormous amount of energy (heat) it takes to raise the temperature of Earth's atmosphere, oceans, and surface by just 1 °C.

I would not qualify Day's acquaintance from the embassy as a legitimate skeptic unless that person has some basic understanding of climate science.

Frank Lock
(flock@gsu.edu)
Georgia State University PhysTec
Atlanta PT