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In this issue: Special collection on the environment, sustainability, and climate change[a] FREE

Special Collection: Teaching about the environment, sustainability, and climate change

Kyle Forinash ; Roger Tobin ; Barbara Whitten ; Richard Wolfson ; Beth Parks

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In this issue: Special collection on the environment, sustainability, and climate change[a]

Kyle Forinash,[b] Roger Tobin,[c] Barbara Whitten,[d] and Richard Wolfson,[e] *Guest Editors*
Beth Parks,[f] *Editor*

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Physics plays a vital role in understanding the environment in general and climate change in particular. As NASA physicist and climatologist Drew Shindell remarked in the American Physical Society's *APSNews 16*(5), "Climate change is all about energy, a subject familiar to any physicist." However, there is no standardized syllabus for environmental physics, and most physics instructors have no formal training in the subject. In this special issue, we've collected 12 papers to help fill that gap. They describe new physics courses on climate and the environment, suggestions for integrating these topics into existing courses, and presentations that will make you better prepared to teach these topics. The supplemental materials for many of these papers are rich with further ideas.

We hope that this special issue, along with papers in the same collection in *The Physics Teacher*, will enable physics instructors to include these topics in their courses at all levels, from special introductory classes to advanced physics courses. These are important topics, and physics has much to contribute to their understanding and solution. In addition, students are concerned about these issues and appreciate the opportunity to learn more about them. Teachers can design new courses to specifically address issues of the environment, sustainability, and climate change. They can introduce new units into their existing physics courses at all levels. They can design new assignments, laboratory exercises, and field trips to address these topics.

We also hope this collection will inspire physics instructors to develop additional ideas for teaching students about the environment, sustainability, and climate change that can be shared in future issues of *AJP*.

Several of the papers in this issue describe entire courses focused on these topics:

Claire Akiko Marrache-Kikuchi, Guillaume Roux, Jean-Marie Fischbach, and Bertrand Pilette in "A course on climate change and sustainable building design" describe a novel course for intermediate-level undergraduate physics majors that combines a study of human-caused climate change with practical aspects of building design. Students are introduced to global climate issues and, for half of the course, are asked to work on group projects involving literature reviews, modeling tasks, and/or laboratory experiments related to practical aspects of decreasing the human impact on climate. https://doi.org/10.1119/5.0137570

Stefano Toffaletti, Marco di Mauro, Massimiliano Malgieri, Tommaso Rosi, Eugenio Tufino, Pasquale Onorato, and Stefano Oss in "A teaching-learning sequence about climate change: From theory to practice" have designed and tested an entire undergraduate course taught through a series of experiments involving the interactions of light and matter. The sequence of activities is designed to introduce the students to key phenomena and concepts required to understand the greenhouse effect, such as thermal emission of infrared radiation, wavelength-dependent absorption of radiation, and the establishment of a steady-state temperature by the balance between incoming and outgoing energy. The course culminates in the construction of simple models of the Earth's energy balance with and without an atmosphere. https://doi.org/10.1119/5.0137089

In "Teaching physics in the woods," Frédéric Bouquet, Julien Bobroff, Lou-Andreas Etienne, and Clara Vardon describe an unusual class that introduces students to a nearby forest and asks them to explore a range of topics in physics in the natural world. https://doi.org/10.1119/5.0143470

Other contributions describe topics, units, or questions that could be implemented in existing or new courses:

Lane H. Seeley in "Tutorials on climate modeling" reports on using a set of tutorials for teaching about human-caused climate change in an undergraduate physics course open to students from across the campus at Seattle Pacific University. The tutorials lead students through the construction of simple algebraic models and simulations of global climate. Students in this class learn some of the core scientific arguments on which the scientific arguments for human-caused climate change are based. https://doi.org/10.1119/5.0134144

Mikkel Herholdt Jensen, Eliza J. Morris, and Michael W. Ray have written in "Implementing a course-based authentic learning experience with upper- and lower-division physics classes" about the interactions between students in two physics courses at California State University, Sacramento. In one upper-level advanced electronics course, students design instruments and a user interface for measuring pollution in a local river. Students in a lower-level course use the instruments and act as testers, giving feedback to the upper-level course. Both groups of students come out of their respective courses with a better understanding of how physics can be used to solve real-world problems. https://doi.org/10.1119/5.0137141

Abigail Daane and Jesse Noffsinger in "Essential climate change conversations for introductory physics courses" take a broader perspective, laying out a set of general questions about climate change and the greenhouse effect that, they argue, all students should learn about in college-level introductory physics courses. Their focus is less on the underlying physics and more on what we know about the causes and effects of climate change, what can and should be done about them, and how we can take actions to help bring about those changes. https://doi.org/10.1119/5.0137210

Enjoy a balloon flight? See the paper by Gerard Blanchard, Bryce A. Bowlsbey, James R. Dyess, Ryan D. Rumsey, and Justin B. Woodring, "Improved spectral photometer for undergraduate observations of atmospheric infrared heat flux and greenhouse gas absorption bands." Blanchard *et al*. describe instrumentation built by undergraduate students to measure infrared fluxes, both up and down, with important implications for climate. The students fly their instrument on a high-altitude balloon, and also construct and operate a ground-based version. https://doi.org/10.1119/5.0135029

In "Footprinting in a course on energy," Seth Major provides an introduction to energy footprinting, a method of calculating the amount of carbon emitted in the production, use and disposal of an object or in the completion of a process. He then explains how he uses footprinting in his courses at different levels. https://doi.org/10.1119/5.0136958

Two separate papers provide detailed understandings of the greenhouse effect, its role in global warming, and the importance of feedback effects in establishing climate sensitivity to increasing atmospheric CO_2. "Effects of greenhouse gases on Earth, Venus, and Mars: Beyond the one-blanket model," by Philip Nelson explains the basic physics of the greenhouse effect beyond simple models often used in classes by including some less appreciated aspects of fundamental atmospheric physics at a level appropriate to advanced undergraduate classes, and also compares Earth with other planets, especially Venus. "Climate sensitivity from radiative-convective equilibrium: A chalkboard approach" by Nadir Jeevanjee goes still deeper into the mathematics of the greenhouse effect and provides quantitative estimates of important feedbacks including that of water vapor. Both authors stress the importance of convection in establishing Earth's energy budget, consider the role played by the absorption spectra of greenhouse gases, and recognize the significance of the emission level high in the atmosphere, which defines the planet's effective radiating temperature as seen from space and whose rise with increasing CO_2 concentration results in a higher surface temperature. https://doi.org/10.1119/5.0125523, https://doi.org/10.1119/5.0135727.

Roger Tobin, in "Semiquantitative reasoning can help students track energy and understand conservation: Examples and results from a course on sustainable energy" argues that the focus in typical physics courses on energy problems amenable to exact calculation could interfere with students' ability to track energy in complex real-world contexts. He describes using Energy Cubes, a semiquantitative, manipulable physical representation scheme, to teach about energy flows in environmental situations. https://doi.org/10.1119/5.0129686

This issue also includes a thoughtful review by Nadir Jeevanjee of Steven Koonin's skeptical book *Unsettled: What climate tells us, what it doesn't, and why it matters.* https://doi.org/10.1119/5.0154687

Taken together, these papers provide a wealth of ideas and resources for instructors interested in bringing environmental, sustainability and, especially, climate topics into their physics courses. We hope you find them interesting and useful.

In addition to the articles found in this edition of AJP, readers will find more resources in the following Resource Letters:

Stephen E. Schwartz; Resource Letter GECC-1: The Greenhouse Effect and Climate Change: Earth's Natural Greenhouse Effect. American Journal of Physics 1 August 2018; 86 (8): 565–576. https://doi.org/10.1119/1.5045574

Kyle Forinash and Barbara Whitten; Resource Letter TEP-1: Resources for Teaching Environmental Physics. American Journal of Physics 1 June 2019; 87 (6): 421–432. https://doi-org.exlibris.colgate.edu/10.1119/1.5094745

Stephen E. Schwartz; Resource Letter GECC-2: The Greenhouse Effect and Climate Change: The Intensified Greenhouse Effect. American Journal of Physics 1 September 2018; 86 (9): 645–656. https://doi.org/10.1119/1.5045577

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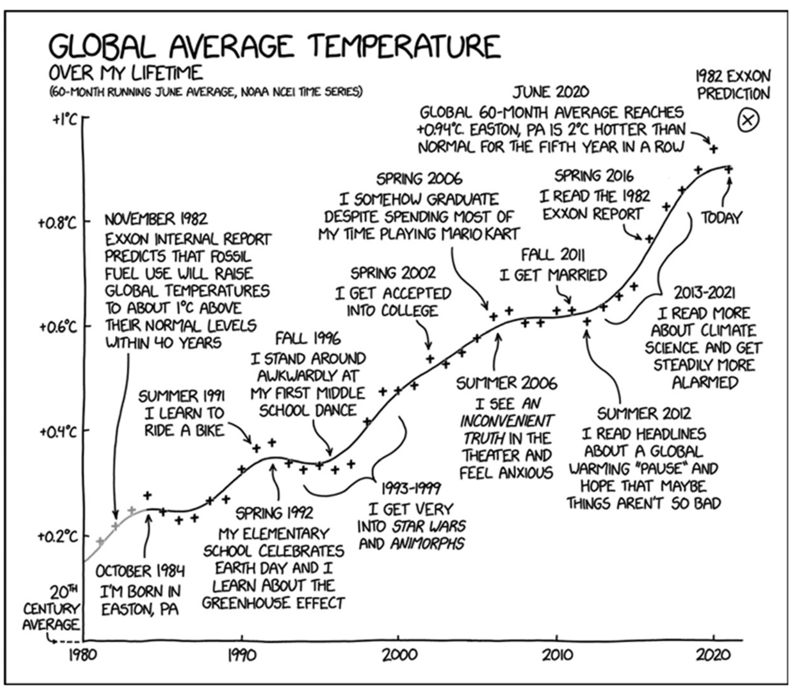
[b]ORCID: 0009-0004-4931-7997
[c]ORCID: 0000-0001-6055-6025
[d]ORCID: 0009-0005-0140-5741
[e]ORCID: 0009-0006-5395-9655
[f]ORCID: 0000-0003-1232-2472



I was really impressed by the accuracy of some of the report's predictions about fossil fuel consumption, Then I realized, oh, right, of course.
(Source: https://xkcd.com/2500/)