clearly shows the conducting properties of a semiconductor at various conditions. By the last lecture in that section, the students understand the principle.

Using new technologies. With the ever-increasing availability of online education resources, including open courseware, online courses, and discussion forums, choosing the best resources is becoming a new challenge for instructors. However, electronic resources provide new tools and opportunities to increase students' conceptual understanding.

I have adopted a lot of electronic resources in teaching both Thermal Physics and Electromagnetism. For example, Bose–Einstein condensation and superfluidity are subtle processes that can be hard to understand, and few laboratory teams have achieved those results experimentally. Videos played in the classroom allow students to watch the phase transition when liquid helium-4 is cooled to a temperature of 2.17 K and becomes a superfluid.

References

1. J. B. Biggs, *Student Approaches to Learning and Studying*, Australian Council for Educational Research (1987).
2. K. Aikawa et al., *Science* **345**, 1484 (2014).
3. E. B. Li et al., *Nat. Commun.* **5**, 3225 (2014).

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A universal law of procrastination

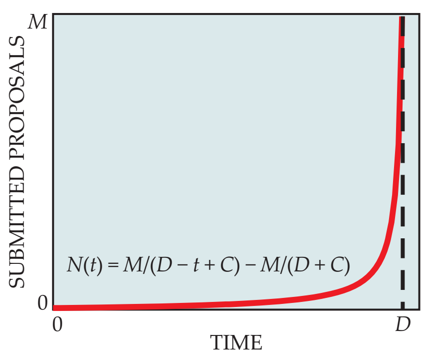
Throughout our lives we all are under pressure to deliver on deadlines. Yet we often have a substantial time window in which to complete the given tasks—for example, term papers, book chapters, tax returns. When during such a window do we deliver? And to what extent do we procrastinate?

Increasing pressure forces us to finalize tasks. The closer we are to the deadline, the higher the pressure. To quantify things a bit, we could assume that deadline pressure is inversely proportional to remaining time. Such scaling behavior is well known in physics; for example, it describes how the electrostatic potential energy of a point charge depends on distance from the charge, or how the gravitational potential energy of a system of masses scales with distance between the masses.

The scales look like $1/r$, where r can be distance, remaining time, or some other factor. The corresponding mathematical function is a hyperbola. To give an example of the scaling using arbitrary and dimensionless units, if a deadline is 100 days away, the pressure to meet it is just 0.01. But if the deadline is tomorrow, the pressure shoots up to 1.

As it turns out, that scaling may be universal when it comes to human behavior and perhaps reflects a universal law of procrastination (ULP). Cornelius König and Martin Kleinmann reported a hyperbolic "deadline rush" for a small set of fewer than 30 students preparing for exams over a 21-day period.[1]

As a program director at NSF, I was impressed by the tremendous increase in the number of proposals routinely submitted right before deadline as compared with those turned in earlier in the submission window. In analyzing large data sets from 10 annual submission



PROPOSED MODIFIED HYPERBOLIC function reflecting a universal law of procrastination. The red line represents the full form of the law, which illustrates the hyperbolic scaling, $N(t)$ is the number of submissions received by day t, M is the final number of proposals submitted, and D is the number of days in the submission window. According to the universal law of procrastination, $N(t) = M/(D - t + C) - M/(D + C)$, where $C = \frac{1}{2}(\sqrt{D}\cdot\sqrt{4 + D} - D)$ helps improve the fit for small values of t. The second term in the right-hand side of the equation ensures that $N(t) = 0$ at $t = 0$. Asymptote (not shown) is located at $t = D + C$.

windows of greater than 60 days with submissions from more than 1000 proposers annually, I have found that the data adhere to a modified hyperbolic function, as plotted in the figure. The model is simple, which means it omits factors such as delays introduced by the universities' sponsored research offices. Nevertheless, the procrastination behavior is predicted quite well, and without any fitting parameters.

As is shown in the figure, the ULP curve provides a simple means of predicting the impact of proposal pressure and of estimating the number of proposals expected as a function of remaining time to deadline. Practical concerns for a receiving institution include how to handle the number of proposals received on the deadline date and whether that load will overtax or crash the existing computer infrastructure.

Bear in mind, though, that hyperbolic functions diverge to infinity at the asymptote. To procrastinating submitters, the most critical issue is that by waiting until the deadline or close to it, they eliminate the time needed for identifying and correcting errors that could make their proposal ineligible for consideration.

I appreciate helpful discussions with Andy Lovinger at NSF and the encouragement of Cornelius König of Saarland University. Any opinions expressed in this material are mine and do not necessarily reflect the views of NSF.

Reference

1. C. J. König, M. Kleinmann, *J. Psychol.* **139**, 33 (2005).

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Pictures of climate change

Spencer Weart's article on climate impacts (Physics Today, September 2015, page 46) describes the sociology of how opinion has evolved on anthropogenic change, but it says little about the opinion's scientific content. It is remarkable that the scientific giant in this field, Svante Arrhenius (1859–1927), without knowledge of the Planck function—much less the quantum mechanics of molecular opacity or computer codes—made predictions of climate sensitivity that are within a factor of two or three of modern estimates. Was that a lucky guess, or is the phenomenon so robust that even the crudest estimates are almost as good as the most sophisticated?

Weart describes, but does not explain, how the consensus about the effects of climate change has shifted from equanimity to fear and trembling that a great disaster will ensue. Is climate change a phenomenon to be observed, like the weather? Is it of direct concern mostly to farmers? Or is it a problem to be solved, and if so, how urgently? The shift is a sociological phenomenon that calls for explanation, but not by physicists.

The physical principles have long been known, and François Massonnet's Commentary in the same issue (page 8) explains that even our present understanding and computational capabilities are not sufficient to predict regional effects such as droughts and floods. The fact that multiphysics codes—which combine multiple models to simulate complex phenomena—could not predict the failure of National Ignition Facility targets should make us skeptical of their power to predict any complex phenomenon, and climate is more complicated than a laser target.

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Having formerly worked for the National Weather Service for 40 years, including assignments at the National Severe Storms Forecast Center and various field forecast offices, I was struck by the images in Spencer Weart's article "Climate change impacts: The growth of understanding." I thought it was interesting that the editors chose to illustrate the article with several weather-disaster photos.

The cover photo shows flooding of small fields lined with palms and other tropical fauna. Other photos show drought and floodwaters extending halfway up storefront shops.

The inference, I suppose, is that climate change caused those weather disasters, despite the author's stating he was unable "to present a convincing case, based on logic and observations, of why anyone should believe the consensus statements" about climate change impacts.

Those photographs perhaps make it more pleasing visually to leaf through a publication, but their inclusion only perpetuates the myth that individual storms are the result of climate change. For example, the vast majority of the flooding shown in the Hurricane Sandy photo was due to the storm surge that typically accompanies hurricanes. The track of Hurricane Sandy was an outlier in the data set. The unusual flooding can be explained entirely by storm dynamics over the ocean. A sea-level rise of several inches due to ice melt would not by itself cause 20- to 25-foot storm surges.

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▶ **Weart replies:** Jonathan Katz worries about the validity of computer studies of projected impacts of climate change. And John Curran notes that illustrations to my article show particular events, which computer studies indeed have difficulty attributing individually to climate change. I apologize if any reader jumped to the conclusion that a specific attribution was intended. I wanted only to illustrate the subject of the article—namely, impacts in general. Still, part of the sea-level rise of the past century is reliably attributed to global warming, and the rise did extend the area of Sandy's inundation. And a peer-reviewed study has reported that global warming did contribute to the Texas drought that was illustrated.

For reasons of length I had to leave out the interesting story of attribution studies of particular impacts; for a sketch and references see http://www.aip.org/history/climate/impacts.htm. Researchers have labored for decades to test computer models against observations, and the matches have been good although imperfect. Anyway, it is not computers but simply the thermal expansion of water and the visible decay of ice sheets that support expectations of further sea-level rise if greenhouse gas emissions continue. Other serious impacts have already been observed in weather statistics, including global intensification of heat waves and of extreme precipitation events.

Finally, Curran misunderstands a