



The
40th
JOHN D.
REGISTER
LECTURE

Life, Liberty, and Thermodynamics



ANDY REX

PROFESSOR OF PHYSICS

Thursday, Nov. 21, 2013

7:30 p.m. | Tahoma Room, Commencement Hall

Reception following lecture

Life, Liberty, and Thermodynamics

THE STUDY OF THERMODYNAMICS is fundamental across scientific fields. For example, geologists know that thermal energy is an essential feature of rock formation near the surface and in geomagnetism, which arises in Earth's molten core. Chemical reactions involve thermal energy, enthalpy, entropy, and two kinds of free energy. Those same concepts apply in biochemical reactions, which interest biologists. Life depends on biochemistry working so that reactions proceed in the proper direction and at a suitable rate to allow cells and whole organisms to form. Living organisms then interact thermodynamically with their environment. Humans can only live within a narrow range of external temperatures. We are constantly exchanging thermal energy with our environment, in order to maintain an even narrower temperature range within the boundaries of our skin. Doing so requires not only careful interaction with our environment but also proper use of food and oxygen we take in from outside. These are all thermodynamic processes.

Living in the modern world requires production and consumption of large amounts of energy. Today this is an important and contentious subject. The increasing worldwide demand for energy requires the use of multiple sources: fossil fuel, nuclear, hydroelectric, solar, wind, and geothermal. Understanding how each of these sources is used requires the laws of thermodynamics. The First Law says that you can move energy around and change it from one form or another, but you can't create any new energy that isn't already there. The Second Law tells us that moving around energy generates waste, a certain amount of which is unavoidable. Some of the waste shows up as thermal pollution and greenhouse gases, which threaten to change our environment and climate.

The sources, production, and use of energy on a large scale would be the subject of another lecture, perhaps given by a future Regester lecturer. What has interested me for some 30 years is whether the laws of thermodynamics are absolute, or whether there are exceptions. Regarding the First Law, there seems little doubt. Energy is always conserved, as long as it's understood to include mass-energy and every form of potential energy.

The Second Law is more interesting. For one thing, it can be expressed in different ways. One of these involves the concept of entropy, which itself has different definitions. Entropy is most easily related to the flow of heat, the energy that passes from warmer to colder bodies. But entropy is also defined in terms of the statistical arrangement of a system of particles, apart from any flow of energy. These different definitions seem to be equivalent, yet they say very different things.

Entropy is a strange concept. Physicists rely on conservation laws and conserved quantities to understand many things. For example, electric charge, mass-energy, momentum, and angular momentum are conserved rigorously. Entropy is not conserved but rather grows without bound. The growth of statistical entropy is specified in terms of probabilities and tendencies, not certainties, yet chemists have tabulated fairly precise values of entropy generated in specific reactions. This gives us confidence that entropy will grow at a predictable rate in bulk reactions.

However, might the situation be different when individual atoms or small particles are considered? There is some precedent for thinking this way. The laws of classical mechanics, which seem so firm for large-scale systems, are overruled by quantum mechanics when the system being studied is small enough. Because entropy is formulated statistically, one has to wonder whether the patterns that seem so reliable for large numbers can be broken on a sufficiently small scale. This idea occurred to James Clerk Maxwell, one of the founders of statistical thermodynamics, in the middle of the 19th century. He imagined a device—later called “Maxwell’s demon”—that could reroute individual particles in a way that reverses the expected statistical pattern.

I’ve spent years studying challenges to the Second Law, including Maxwell’s demon. You’ll hear about some of these tonight. Today there are various schemes for manipulating small systems, even individual molecules. But can you reverse the Second Law and decrease entropy? Could you ever do this reliably and on a large enough scale to make it interesting? Could you ever plug your computer into your bathtub?

These studies teach us a lot about the laws of nature. They may also teach us something about life, not just as the biochemist thinks of it, but rather something for everyone to contemplate, as we each decide how best to live our own lives. The constraints imposed by the Second Law and other laws of nature set limits on all physical systems, including living things. We have to face those limits squarely and decide what they mean. Are these limits roadblocks that impede us, challenges to overcome, or something else? I will address the questions we face as we contemplate the limits imposed by physical laws.

Andy Rex

PROFESSOR OF PHYSICS

ANDY REX WAS BORN AND RAISED IN PEORIA, IL. Like many other children at that time, his first encounter with physics came by watching the progress of the manned space program, culminating in the lunar landings of the late 1960s and early 1970s. From an early age he loved school and learning, and he spent summers playing baseball, listening to his beloved Cardinals on the radio, and delivering newspapers to earn money for college.

After a first taste of academic physics in high school, Andy was inspired to major in physics in college. He attended Illinois Wesleyan University, an old liberal arts college in the middle of an old Midwestern town. The liberal arts curriculum was a good fit, allowing Andy to follow his passions to study not only physics but other subjects, including mathematics, German, and history. He went on to graduate school at University of Virginia, where he earned his Ph.D. in 1982. Andy's research at Virginia was in novel superconducting compounds. This afforded him a firsthand encounter with extremely low temperatures: 4.2 K and lower, using liquid helium as a refrigerant.

Andy went directly from graduate school to University of Puget Sound. In 31+ years here he has taught most of the courses in the physics curriculum. He has taught physics majors, other science majors, and liberal arts students. One day while preparing to teach a modern physics class unit on statistical physics, he read about Maxwell's demon and decided it would be a good example for the class. Now almost 30 years later, it's still a good example for physics students or anyone who wants to understand the Second Law of Thermodynamics. In that time Andy has written several articles and two books on the subject.

Published textbooks have grown organically from Andy's teaching assignments. That modern physics class led to the first textbook, now in its fourth edition. In the 1990s Andy and colleague Martin Jackson worked together to develop an integrated physics and calculus experience for students, and they co-wrote a textbook for the course. Many years of teaching the algebra-based college physics class at Puget Sound resulted in another textbook: *Essential College Physics (ECP)*. ECP was designed to be lean but comprehensive and thereby break the cycle of textbook inflation, which refers to the growth of textbooks in both price and mass.

Through all the years, Andy has been well supported by family. First, his parents encouraged his education and scientific interests. Now, for more than 20 years, Andy's wife, Sharon, and daughter, Jessica, have alternately encouraged and tolerated his various academic passions, from class to class and book to book. With them it has been and continues to be a glorious existence!

John D. Regester Faculty Lectureship

THE JOHN D. REGESTER FACULTY LECTURESHIP was established in 1965 to honor the service of John. D. Regester, Ph.D., who joined the Puget Sound faculty in 1924. Regester taught philosophy throughout his career, served as dean of the university, and later was made first dean of the Graduate School.

Under the terms of the lectureship, the address is to be given by a member of the university who exemplifies the qualities of scholarship and intellectual integrity which professors and students have long associated with Regester.

The lecture series is a means of honoring members of the university faculty through an opportunity for them to address the university community on a subject of particular interest to the lecturer. The John D. Regester Lectures are both a recognition of the scholarship and accomplishments of the lecturer and an opportunity for the faculty to develop ideas further and explore them with colleagues and the public. The lectures provide a showcase where students and faculty members can witness their colleagues in the role of productive scholars.

2012—George S. Tomlin, occupational therapy	1989—Kenneth Rousslang, chemistry
2011—Nancy Bristow, history and African American studies	1987—Terry A. Cooney, history
2010—David Lupher, classics	1985—Beverly K. Pierson, biology
2009—Suzanne Holland, religion	1983—Douglas M. Branson, law
2008—David Tinsley, German	1981—Michael J. Curley, English
2007—D. Wade Hands, economics	1980—Esperanza Gurza, foreign languages
2006—A. Susan Owen, communication studies	1979—Francis L. Cousens, English
2005—Mott T. Greene, history	1978—Delmar N. Langbauer, religion
2004—Doug Edwards, religion	1977—Jeffrey S. Bland, chemistry
2003—Rob Beezer, mathematics	1976—Esther B. Wagner, English
2001—Geoff Proehl, communication and theatre arts	1975—Richard E. Hodges, education
2000—Helen (Ili) Nagy, art	1974—Theodore L. Harris, education
2000—James Evans, physics	1973—Z. Frank Danes, physics
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1998—Denise L. Despres, English	1971—Robert G. Albertson, religion
1997—William Breitenbach, history	1970—John W. Prins, business
1995—Alan S. Thorndike, physics	1969—Leroy Ostransky, music
1993—George M. Guilmet, comparative sociology	1968—Gordon D. Alcorn, biology
1991—Michael Veseth, economics	1967—John D. Regester, philosophy
	1966—Harold P. Simonson, English
	1965—John B. Magee, religion



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