HCOL 185
Energy Dynamics in a Complex Universe
Honors College Seminar

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Course Description

Energy is a dynamic quantity that pervades space and time to their limits. Continuously changing form, morphing from one type to the next, never created nor destroyed, yet always decaying from a highly ordered state to one with many possibilities, energy is the stuff that manifests matter and the thing that manifests time. The dynamics of energy fabricate reality and elucidate existence, and yet, at the same instant, conceal the future from observation until it becomes the now.

Energy is a term that is often used in colloquial conversations yet is rarely subjected to rigorous definitions nor to critical thought processes and analyses. Even still, the scientists and engineers who make their livelihood studying, shaping, converting, and manipulating energy will necessarily admit, if they are honest, that even they do not truly know what energy actually is. That's correct; there is very little scientific agreement as to what energy actually is. Yet enigmatically, humans have become incredibly proficient at quantifying, tracking, and manipulating energy.

A glib and unsatisfying definition of energy is that it is everything in existence. Yet, one might argue that this is, in fact, a quite accurate and rigorous definition as well. In this class, we will strive to fill in the spectrum between glib and rigor as we explore the transient nature of energy and its influence on our physical reality from the smallest of the microscales to the largest scales of the universe.

The first few weeks of this course will be used to develop foundational knowledge pertaining to the scientific method, relevant fundamental concepts, and the basic tools and techniques necessary to perform critical analyses of energy related processes. Students will develop the skills necessary to read, write, think critically, and respond to technical papers as well as articles written for the general public.

A majority of the course will consist of assigned readings with questions that students should be prepared to discuss in class. Several discussions will take place in debate form where students will have to be prepared to argue both sides of a topic. Other times, students will be tasked to present a new topic to the class and chair the ensuing discussion. Additionally, there will be a final team project where students will present a more in-depth analysis of a related topic.

Learning Objectives

- Develop a meaningful understanding of the dynamics of energy in the physical universe.
- Understand the process through which new scientific knowledge is generated and employed.
- Learn to assess the validity of and be able to critically analyze various reference types.
- Develop and improve critical thinking skills.
- Practice and improve skills related to technical arguments and debates.
- Practice and improve communication skills (written / public speaking / presentations).
- Understand and develop skills necessary to perform literature reviews and research.

Examples of Discussion Topics

Introduction & Fundamental Concepts

- What is Matter, Space, and Time? Newton's Bucket.
- What is Energy? – Continuum, Statistical, Quantum, Complex System, Equilibrium vs. Non-Equilibrium Systems. Does string theory work?
- What is Entropy? – As disorder, probability, and as "Missing Information."
- What is Quantum Mechanics? – Probability waves and collapse, superposition of states, Pauli exclusion, Heisenberg uncertainty, limitations of measurements.
- What is an energy transformation process? Energy vs. Power. Problems of Scale.
- Relativity & Lorentz Transforms. Simultaneity as a temporal illusion.

Naturally Occurring Energy Systems

- What is gravity – a wave or a particle? Orbital basics and black holes (event horizon (Schwarzschild radius), viewpoint of observer vs. entrant) Tidal Forces.
- Black Holes: 2nd Law and quantum equations, Temp, Charge, Spin.
- Vacuum fluctuations, Bill Unruh's Law, Hawking radiation, Elec. Degeneracy P.
- Maximum entropy *as* empty space.
- Atmospheric Flows & Weather Patterns – Rossby Waves, Jet Streams, teleconnection indices & regime change, convective cells (Hadley, Rayleigh).
- Earth Mantle Asthenosphere flows – ridges, trenches, tectonic plates.
- Biological Energy Systems
- Dissipative systems & Symmetry Breaking; evolution of order from disorder

Human Constructed Energy Systems

- Power Generation & Transmission systems
- Propulsion & Transportation systems
- Forcing energy against the spontaneous direction
- Energy conversion, recovery, and storage
- Energy Efficiency: "Doing more with less."

Course Format

Lecture, discussion, and debate with selected readings; multimedia experiences; written essay responses to assigned readings; short presentations; research project.

Required Book

- Fabric of the Cosmos – Space, Time, and the Texture of Reality – *Brian Greene*
  ISBN: 0-375-72720-5

Reference Books & Selected Readings – *Do not Purchase (TBD)*

- The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics – *Leonard Susskind*
- Black Holes & Time Warps: Einstein's Outrageous Legacy – *Kip Thorne*
- Biological Thermodynamics – *Donald T. Haynie*
- A First Course in Atmospheric Thermodynamics – Grant W. Petty

Examples of Articles – *To be posted on BlackBoard.*

- The Long Arm of the 2nd Law – *Scientific American*
- The Possibilian – David Eaglemen and Mysteries of the Brain – *The New Yorker*
- The True Cost of Fossil Fuels – *Scientific American*
- Is Space Digital? – *Science News*

Evaluation

		Scheme	
• Participation in Discussions	25%	A	90 - 100
• Assignments & Essays	25%	B	80 - 89
• Debates & Presentations	25%	C	70 - 79
• Research Project	25%	D	60 – 69

Academic Integrity

Academic dishonesty will not be tolerated. This course shall be in accordance with the University of Vermont's Code of Academic Integrity as defined by the Center for Student Ethics and Standards. **http://www.uvm.edu/cses/**

"An instrument too often overlooked in our technical world is a human eye connected to the brain of an intelligent human being." – Ralph Peck, PhD, National Medal of Science

Essential Qualities

The following is a brief summary indicating how this course will address all but one of the eight "Essential Qualities" of an Honors College Seminar.

1. *Academically Challenging*: Courses must be appropriately demanding for sophomores, keeping in mind that students in the class may be from any college or school and may not be presupposed to have taken particular courses. However, instructors may choose to introduce foundational material at the beginning of the course.

    - *No background knowledge in science, engineering, or energy systems is assumed. However, students will be expected to apply basic ideas, concepts, theory, and mathematics presented and discussed in class as they work through assignments.*

    - *The main focus of this course will be for students to develop critical thinking, reasoning, and analytical skills as they apply to the scientific topics and concepts of energy and the role of energy in manifesting our observed physical reality.*

    - *This course will introduce students to the fundamental and conceptual definitions of energy and energy transformation processes along with the First and Second Laws of Thermodynamics. Basic college mathematics (geometry, trigonometry, and calculus, i.e., Freshman level differentiation and integration) will be used in the analyses and discussions of the particular mechanisms that nature employs to shift energy from one form to another such as mass, space, time, chemical, thermal, electrical, etc.*

    - *Concepts discussed will be academically challenging and interesting to both scientific as well as the non-scientific minded student. Reading and homework assignments along with a class project will be sufficiently rigorous yet academically feasible for the sophomore level.*

2. *Interactive*: Courses will be seminars (and not small versions of lecture courses), with a great deal of interaction among students and the instructor.

    - *A majority of the classroom experience will revolve around class discussions and questions based on assigned readings. It is expected that all students will participate in discussions and assignments will be designed to facilitate student comfort and preparedness for these discussions.*

    - *This course will include exciting presentations and interactive multimedia that will facilitate orientation of the student to challenging and /or abstract scientific concepts.*

    - *Several topics will be explored through student led presentations in a 'flipped' classroom arrangement. This will provide students with the opportunity to develop public speaking and presentation skills.*

    - *Several topics in this course are inherently debatable. As such, students will be assigned readings and should arrive to class prepared to argue either/both sides of a*

particular argument. This will facilitate critical thinking and the development of the skills necessary to "think on your feet" and process in real time.

3. *Writing Intensive*: In most cases, seminars should emphasize excellence in written communication and expression. Courses emphasizing numeracy and quantitative skills, oral communication, or information technology, are also encouraged.

    - *Several assignments will involve reading scientific journal papers as well as scientific documents written for the general public. The student will then be required to formulate a meaningful written response to the article and to respond in writing to questions posed by the instructor and/or students.*

4. *Research Oriented*: In most cases, seminars should introduce students to aspects of the conduct of research within disciplines or interdisciplinary clusters. These seminars aren't viewed as "methods" courses but should allow students to acquire tools that will allow them to gain skills and dispositions that will help them become more active and engaged students, rather than passive recipients of content knowledge. For example, courses may introduce students to how to read a scientific article, annotate a bibliography, conduct field research, devise an experiment, write an abstract, and so on.

    - *This course will introduce students to the scientific method, how to perform literature and scientific article reviews, generate a term paper with proper bibliography, and the proper critical thinking skills necessary to analyze published scientific literature.*

    - *Students will learn the skills necessary to analyze scientific sources, evaluate them for reliability, and to critique the conclusions of a scientific study based on the presented experimental procedure and evidence.*

5. *Creative*: Courses that emphasize intellectual creativity and foster the development of research skills are encouraged.

    - *Extrapolating fundamental and universal concepts to particular and specialized systems is a central theme in this course. Intellectual creativity and the development of "outside the box" thinking is a skill that will be emphasized throughout this course.*

    - *In some cases, students will re-write a section of a scientific document or news article in which they will be tasked to do one or more of the following: make the section more accurate; make the section more accessible to the general public; incorporate modern ideas or recent concepts from classroom discussions; suggest an alternate conclusion; provide motivation and suggest topics for further investigation.*

6. *Multidisciplinary*: Courses emphasizing important relationships among related field of knowledge are encouraged.

    - *Energy is fundamentally multidisciplinary owing to the fact that everything is made up of, interacts with, and consumes energy. The fundamental laws that govern the*

dynamics of energy are intrinsic to many disciplines and can be applied with equal rigor and emphasis to any particular arena.

- *This seminar will explore the dynamics of energy through both technical scientific articles, excerpts of popular science writing, current events, and to a lesser extent, science fiction. (After all, there are many examples where the science fiction of 20 years ago is science fact of today: Is there any evidence to suggest that the science fiction of today will become reality in the future? Surely energy will play a key role.)*

7. *Engage Diversity:* Courses that might satisfy D1 or D2 diversity requirements are strongly encouraged.

   - *It is not expected that this course will satisfy diversity curriculum requirements.*

8. *Innovative*: Courses emphasizing service learning and other forms of non-traditional learning are also encouraged.

   - *Several class meetings will require prior research on the part of the student. The student will then present their findings to the class in a "flipped-classroom" environment.*

   - *Student debates, multimedia demonstrations, and other novel classroom experiences will enhance the non-traditional learning environment.*