PHYSICS 137SK

# Energy in the 21st Century and Beyond

**Spring 2017**

Dates / contact hours: 300 contact minutes (3 meetings per week is preferred) / week for 7 weeks
Academic Credit: 1 course
Areas of Knowledge: NS
Modes of Inquiry: STS
Course format: Each meeting consists of a mix of lecture, discussion, and group problem-solving. (can accommodate up to 18 students)

## Instructor's Information

Jian-Guo Liu, Professor, Department of Physics and Department of Mathematics, Duke University

## Prerequisite(s), if applicable

Pre-calculus and at least one quantitative science course at high school level.

## Course Description

A seminar course covering the fundamentals of energy science and related emerging technologies, presented at a level that is accessible to students from all undergraduate majors. Concepts of energy from a scientific perspective for understanding problems of energy conversion, storage, and transmission in modern society. Topics include fundamental concepts (kinetic and potential energy, heat, basic thermodynamics, mass-energy equivalence), established power generation methods and their environmental impacts, emerging and proposed technologies (solar, wind, tidal, next generation nuclear fission and fusion concepts). The economic and environmental implications of different energy technologies will also be analyzed and considered. Final team project. Prerequisites: Pre-calculus and at least one quantitative science course at the high school level, such as chemistry or physics. Can accommodate up to 18 students.

## Course Goals / Objectives

Students will be expected to master the course material at several different levels, from defining and describing information (lower level) to assessing, evaluating, creating, and integrating information (higher level). Assignments will be aligned with course objectives in a logical manner. Because several of the assignments are written essays and class presentations, students will be expected to display skills in the logical development of an argument, proper literature citations, and other aspects of scientific writing. Rubrics for evaluation will be provided for all assignments so that students will understand the expectations for each task. Because most of the anticipated students for this course will be using English as a Foreign Language (EFL), the rubrics will be similar to the Duke University version of this course, but also specifically appropriate for EFL students.

Course goals and objectives are very similar to those in the Duke University version of this seminar course. Due to the 7-week period for the proposed course versus the approximate 14-week period for the Duke University course, the pace of the proposed course will be approximately double that of the Duke University course. The course requirements and assignments in this course proposal are specifically paced to fit in with the shorter timeframe.

## Required Text(s)/Resources

- *Energy Science: Principles, Technologies, and Impacts*, 2$^{nd}$ edition, by John Andrews and Nick Jelley (Oxford University Press, 2013

- Instructor supplementary notes.
- Students will use articles from the primary research literature, contemporary and popular science online publications, as well as review articles and other bibliographic sources. Energy-related articles will come from contemporaneous publications such as Nature News and Comments, IEEE Spectrum, Physics Today, The Economist, New York Times, and the Wall Street Journal.

Readings are assigned to match the topics covered in class. Typically, one chapter of the text and corresponding instructor supplementary notes, along with two or three short articles are all assigned for each class meeting. The goal is to have students read a classic pedagogical exposition of the science that underlies the energy-related topic of the corresponding class along with short articles from contemporary publications that show how the fundamental science is being applied to current technological and societal problems.

## Recommended Text(s)/Resources

- *Sustainable Energy – Without the Hot Air*, by David J. C. MacKay (UIT Cambridge, 2009) [also available online at http://www.withouthotair.com/].

## Additional Materials (optional)

PowerPoint

## Course Requirements / Key Evidences

- Homework exercises (5 assignments) = 30 %
- 5 Mini-reports on current developments in energy science = 15 %
- In-class participation = 20 %
- Final team project = 30 %
- Reviews of team projects = 5 %

## Technology Considerations, if applicable

The Duke Sakai system will be used. The lectures and discussions will be conducted through a combination of PPT and board presentations supplemented by online resources.

## Assessment Information / Grading Procedures

Rubrics for written essays will be provided ahead of time and students will be given their evaluation sheets from scored rubrics. ESL students will receive advice and counseling on their English skills if required or will be referred to the English Writing courses offered at DKU by the Thompson Writing Program faculty and/or ESL faculty. A rubric for the PowerPoint group presentation will also be created.

## Diversity and Intercultural Learning (see Principles of DKU Liberal Arts Education)

The instructor has extensive prior experience teaching and supervising research projects for students from a wide range of backgrounds, including visiting Chinese high school and university students, as well as Chinese exchange students in the Physics Department at Duke University. He will also recruit colleagues from Chinese universities for co-teaching and guest lectures. All aspects of the classroom experience, from field trips to group presentations to library work, will be accomplished with attention to intercultural sensitivity and awareness of global cultural diversity.

## Course Policies and Guidelines

- The final team projects will be accomplished by student groups (with 3-4 students per group) . Each group will work with the instructor and one another on the presentation and submit ppt slides to the instructor for detailed feedback before the class presentations which will take place during the final week of class meetings. Each group may select one person to make the presentation to the entire class or choose to divide the time among group members. All team members are expected to participate actively in the Q&A session.
- While group discussion and collaboration are highly encouraged, students are always expected to follow The Duke Community Standard. Details about the Duke Community Standard can be found at http://studentaffairs.duke.edu/conduct/about-us/duke-community-standard.
- Students are required to attend all classes. Absence will be excused for special circumstance such as illness, family emergency upon written request in advance.

- All required work needs to be submitted on or before the published due date. In special cases such as illness and family emergency, extension may be granted following written request.
- Cell phone use is not allowed during classes, laptop use in class is allowed only for searching for information relevant to the class discussion with the permission of the instructor.

## Tentative Course Outline or Schedule

**Syllabus**

The class meets 2 times a week with 150 minutes per meeting.

**Week 1:** Survey of key fundamental principles of physics

Lecture 1: Different forms of energy (mechanical, electrical /chemical, gravitational, and nuclear).

Lecture 2: Conservation of energy and momentum; energy conversion and efficiency.
the Laws of Thermodynamics; heat engines, refrigerators and power plants.

Readings: MacKay, Chapters 1 – 3 and 7; additional readings to be assigned.

Assignments: Homework #1; Mini-report #1

**Week 2:** Fossil fuels; wind energy

Lecture 1: Energy from fossil fuels – coal, oil, and natural gas.

Lecture 2: Hydrodynamics and aerodynamics; turbines for hydroelectric and wind power.
Wind turbine designs; mini-lab #1 on a small-scale wind turbine.

Readings: MacKay, Chapters 4, 5, 8, 10, and 14; additional readings to be assigned.

Assignments: Homework #2; Mini-report #2

**Week 3**: Solar energy

Lecturer 1: Photons, light and solar energy.

Lecturer 2: Survey of photovoltaic cell function, materials and technology.
Solar cell conversion efficiency; mini-lab #2 to measure the efficiency of a solar cell.

Readings: MacKay, Chapters 6, 9, and Appendix D; additional readings to be assigned.

Assignments: Homework #3; Mini-report #3

**Week 4**: Nuclear power from fission and fusion

Lecture 1: Introduction to the strong force and nuclear binding.

Lecture 2: Current and proposed fission reactors.
Proposed fusion reactors including tokomak and stellarator designs.

Readings: MacKay, Chapter 24; additional readings to be assigned.

Assignments: Homework #4; Mini-report #4

**Week 5:** Energy storage and transmission

Lecture 1: The need for energy storage in conjunction with renewable sources; basic operational principles of batteries and fuel cells.

Lecture 2: Survey of current and proposed batteries and fuel cells; materials challenges.
Energy transmission and the power grid.

Readings: MacKay, Chapters 18 - 22, and 26; additional readings to be assigned.

Assignments: Homework #5; Mini-report #5

**Week 6:** The relative economic and environmental impacts of energy technologies

Lecture 1: Energy for transportation.

Lecture 2: Impact of different energy technologies on the environment at local and global scales.
Life-cycle analysis – a comprehensive method to compare the costs and benefits of different energy technologies.

Readings: MacKay, Chapters 15, 20, 31, and Appendix H; additional readings to be assigned.

Assignments: Preparation for team presentations: review of draft presentations including reference materials.

**Week 7:** Team presentations and discussion including written presentation reviews to be completed by all students.

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