GEOS 24705/34705, ENST 24705 / ENSC 21100 (2018)
Energy: Science, Technology, and Human Usage

Professor: Liz Moyer (moyer@uchicago.edu, Hinds 405, office hour TBD)
Teaching assistant: Jim Franke
Field trip coordinator: TBD
Website: http://geosci.uchicago.edu/~moyer/GEOS24705/2018

Class: location Cobb 119, T Th 3:30-4:50 PM
Labs: TBD (only 1 hour required)
TA Office hours: TBD

Syllabus

(Field trips are tentative. Additional field trip options may be scheduled during the quarter, depending on student interest and opportunities)

Lec 1,2 / Mar. 27, 29

Earth's energy system: Natural energy flows and transformations

- The primary energy cycles of the Earth system
- Energy flow I: hydrological cycle
  * *radiation → latent heat → sensible heat → mechanical work → heat*
- Hydrological cycle efficiency
- Energy flow II: photosynthesis
  * *radiation → chemical energy → (mechanical work) → heat*
- The cascade to heat: qualitative 2nd law of thermodynamics, heat death of universe
- Photosynthetic efficiency, agricultural efficiency, and limits: can the world run on biomass?
- History of rise of human appropriation: pre-industrial to modern usage

In-class demos: feeling a Joule and a Watt
No lab this week.
No field trip this week.

Lec 3,4 / Apr 3, 5

Human appropriation of energy I

- The human engine: food in, work out
- Mechanical efficiency & losses to heat
- Early energy use history: animal power, water, wind; heat for chemistry: metallurgy, ceramics
- Sidebar on fossil fuels - origin, composition, use
- Equivalence of types of energy: first law of thermodynamics
- The heat-to-work barrier
- The first great revolution: heat to work (the steam engine)

Lab: Measuring power - solar flux, thermal IR emission, mechanical work output by humans
No field trip this week.

Lec 5,6 / makeup + Apr 12 *(need alternate time for Tue. 4/10 lecture)*

Heat engines and human appropriation of energy II

- Thermodynamics of heat engines: Carnot efficiency, 2nd law of thermodynamics
- Thermodynamics of heat pumps & refrigeration/air conditioning
- Industrial revolution: the transformation to industrial society

Lab: Chemical energy to heat – calorimetry, fossil fuels, steam engine demo, gas laws
Field trip: Steam engines (Museum of Science and Industry, local trip). (Also cogeneration and solar PV, though in advance of those lectures)

Lec 7,8 / Apr 17, 19

Making electricity by spinning stuff: Electric generators & motors, turbines I

- The second great revolution: large-scale energy transport via electricity
- The great technology framework: energy transformation grid
- Flow of energy in modern society: types, users, efficiencies
- Generators (rotational motion -> electricity)
- ….and the converse of generation, electric motors (electricity -> rotational motion)
- Basics of electrical power, AC vs. DC power, history of electricity transmission

Lab: no lab this week
Field trip: U. Chicago steam and cooling plants (local trip)

Lec 9,10 / Apr 24, 26

Electricity generation & turbines II

- Industrial electrical generation – power plants
- Steam and gas turbines: external vs. internal combustion, condensible vs. non-condensible
- Steam and gas turbines: Rankine vs. Brayton cycles
- Leveraging the higher temps of gas: combined cycle and cogeneration

Lab: Electricity and electric motors I: resistance, magnetism, forces on moving charges, building basic motors, motors as converse of generators
Field trip: coal-fired power plant

Lec 11,12 / May 1, 3

Turbines III (water & wind)

- Energy densities of wind and water flows, Bernoulli's equation
- Hydro turbines: why dams at all?
- Hydro: impulse vs. reaction turbines, hydrostatic head vs. free stream
- Hydro: Pelton, Francis, Kaplan turbines, free-stream turbines -> wind
- Wind: history, design, limitations, areal energy density
- Wind generator constraints, new approaches

Lab: Lighting efficiency (in advance of lecture)
Potential field trip: Wind farm

Lec 13,14 / May 8, 10

Electrical grid and electricity regulation, nuclear power

- Grid introduction: What is it? Electrical transmission, distribution, history
- Grid control (or lack of): brownouts, blackouts
- History of electrical utilities, deregulation
- Grid introduction II: Who owns it? Who builds it? Who pays for it and how?
- Electricity markets – who buys what
- Congestion and congestion pricing, incentives for transmission
- Physics of transmission and distribution
- Renewables and the grid – standards, reactive power, intermittency
- Nuclear power

Lab: Electric motors II: workings of AC and DC motors, torque-speed
Potential field trip: Dresden Nuclear Plant
Deadline: choose project topics and groups

Lec 15,16 May 15, 17

Internal combustion engine + transportation, fossil fuels

- History of ICE technology and automobiles
- Otto cycle, Diesel modification
- Electric & hybrid vehicles (including trains)
- Gasoline vs. diesel vs. electric: torque-speed relationships
- Where energy goes: friction + drag
- Fossil fuels: chemistry, geologic history, extraction, history
- Oil refining
- Fossil fuel resources, production, transportation network, limits

Lab: electricity markets discussion
Potential field trip: Argonne Advanced Auto Lab

Lec 17,18 May 22, 24

Fossil fuels cont., solar, lighting, beg. of industry & building energy use

- Unconventional oil sources
- Synthetic fuels: gasification (Fischer-Tropsch), coal-to-liquids, biodiesel
- Energy return on energy investment and CO2 emissions
- Solar thermal and solar photovoltaics
- Solar PV: technology, usage, market trends
- Brief review of energy storage options
- Commercial and industrial energy usage overview
- LEDS: technology
- Lighting: historical evolution, incandescent, fluorescent, LEDs
- Building energy use and efficiency measures
- Industrial processes: materials energy cost (metallurgy, plastics, chemicals, etc.)
- Agriculture, fertilizer and the Haber-Bosch process

Lab: Internal combustion engines
Potential field trip: BP Whiting Oil Refinery

Lec 19 May 29

Industrial energy use cont., summary and wrap-up

Lab: Solar PV and wind.

Reading period (Th, F May 31-Jun 1)

Potential options for additional field trip: *buildings; steel manufacturing; methane digestion; oil & gas drilling + carbon sequestration; biofuels*

Finals week (Jun 4-8): Presentations of final projects
