GEOS 24705/34705, ENST 24705 (2015)
Energy: Science, Technology, and Human Usage

Professor: Liz Moyer (moyer@uchicago.edu, Hinds 405, office hour W 4:30-5:30 PM)
Teaching assistant: Andrew Malone (amalone@uchicago.edu, Hinds 425
Field trip coordinator: TBD
Website: http://geosci.uchicago.edu/~moyer/GEOS24705/2015

Class: location TBD, T Th 3:00-4:30 PM
Labs: TBD (only 1 hour required)
TA Office hours: TBD

Syllabus

(Field trips are tentative. Additional field trip options may be scheduled after start of class)
Note that class on Tues. March 31 will be short and focused just on logistics and preliminary info-gathering. The first real class is Thurs. April 2 (unavoidable conflict). We will find a makeup time/s for the lost lecture, ideally during the 2nd week of classes.

Lec 1,2 / Apr. 2, 7

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 9 + makeup class

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 / Ap 14,16

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 / Ap 21,23

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 / Ap 28, 30

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 5, 7

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)
Field trip: Grand Ridge wind farm

Lec 13,14 / May 12,14

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
Field trip: Dresden nuclear plant
Deadline: choose project topics and groups

Lec 15,16 May 19, 21

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 (if possible)
Field trip: Argonne Advanced Auto Lab

Lec 17,18 / Liz is gone this week (May 26,28), classes by Skype or find alternate times.

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
Field trip: BP Whiting Oil Refinery

Lec 19 June 2

Industrial energy use cont., summary and wrap-up

Lab: Solar PV and wind.

Reading period (Th, F Jun 4-5)

Field trip: optional possibilities. *Field trip possibilities include buildings, methane digestion; oil & gas drilling; carbon sequestration, steel manufacturing; biofuels*

Finals week (Jun 8-12): Presentations of final projects
