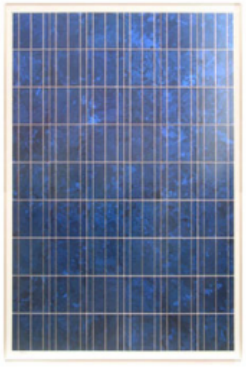
University of Massachusetts Amherst

Lecture 5–Power Generation

ECE 197SA – Systems Appreciation

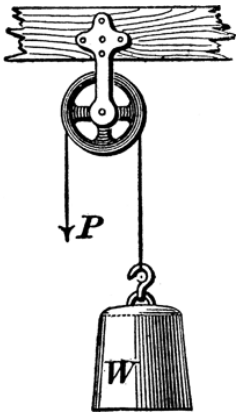
Electric Power

- All ECE systems require electric power
  - Energy needs to come from somewhere
- Energy one of the dominating domestic and international issues
  - US electricity consumption (2008): 3.873 trillion kWh
- Today's lecture: generating electric power from other energy sources
  - Focus on solar cells
- Next week's lecture: distribution of electric power
  - Power grid



Energy vs. Power

- Definition of energy
  - Amount of work that can be performed by a physical system
- Definition of power
  - Rate at which work is performed or energy is converted



Activity

- What are sources of energy?

Sources of Energy

- Mechanical
  - Compressed spring, elevated mass, thrown ball, vibrations
- Thermal
  - Water steam, molten lava
- Chemical
  - Fossil fuels, explosives
- Nuclear
  - Nuclear material for fission or fusion
- Electromagnetic radiation
  - Light, microwaves

- Note: *anything* has energy associated with it
  - In practice it matters if we can extract that energy

Energy Conversion

- Energy can be converted from one type to another
  - Conversion typically not 100% efficient (i.e., energy loss)
- Example devices/processes for energy conversion:
  - (from wikipedia.com)

from \ to	mechanical	thermal	electric	electromagnetic radiation	chemical	nuclear
mechanical	lever	brakes		synchrotron	matches	particle accelerator
thermal	steam turbine	heat exchanger		hot objects	blast furnace	supernova
electric	electric motor	resistor		light-emitting diode	electrolysis	synchrotron
electromagnetic radiation	solar sail	solar collector		non-linear optics	photosynthesis	Mössbauer spectroscopy
chemical	muscle	fire		glowworm	chemical reaction	
nuclear	alpha radiation	sun		gamma radiation	radioactive decay	nuclear isomerism

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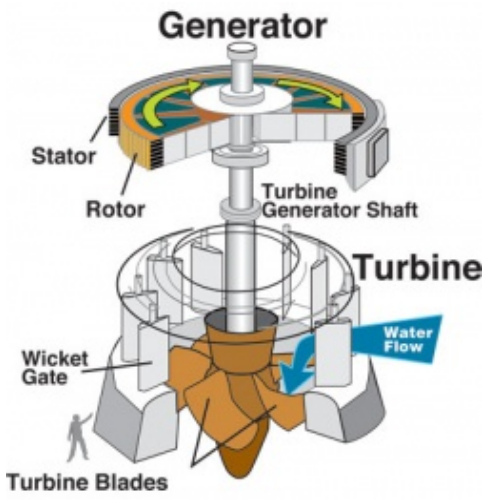
Mechanical to Electric

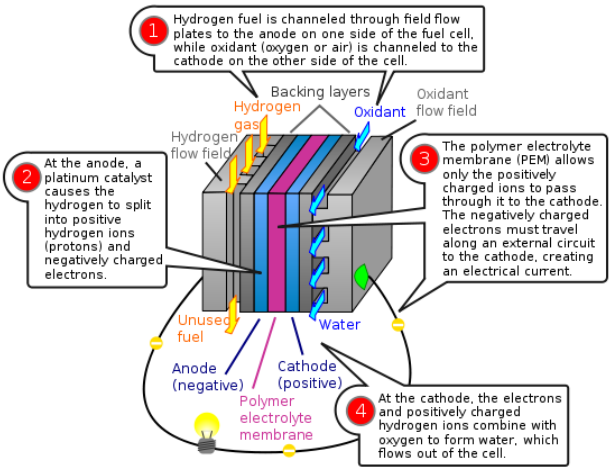
- Hydroelectric turbine



Chemical to Electric

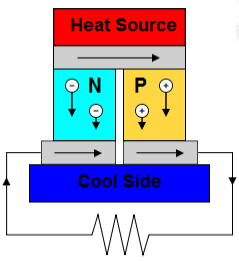
- Fuel cell
  - Chemical reaction directly generates current

Proton exchange membrane fuel cell



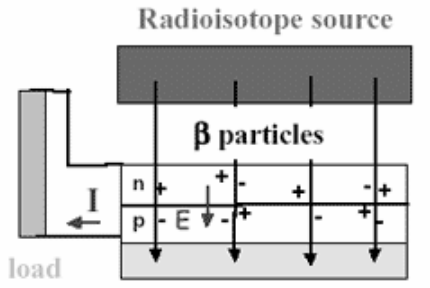
Thermal to Electric

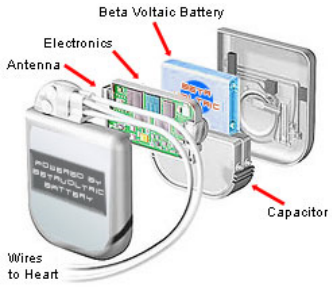
- Thermocouple
  - Thermoelectric effect used to generate voltage



Nuclear to Electric

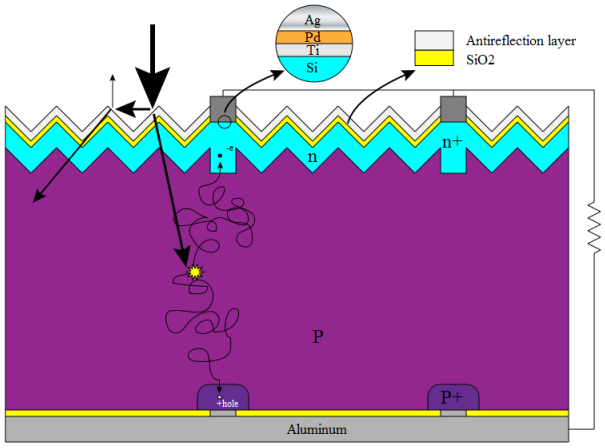
- Betavoltaic cell
  - Beta-particles from radioactive decay induce current
  - Very long lifetime (tens of years)



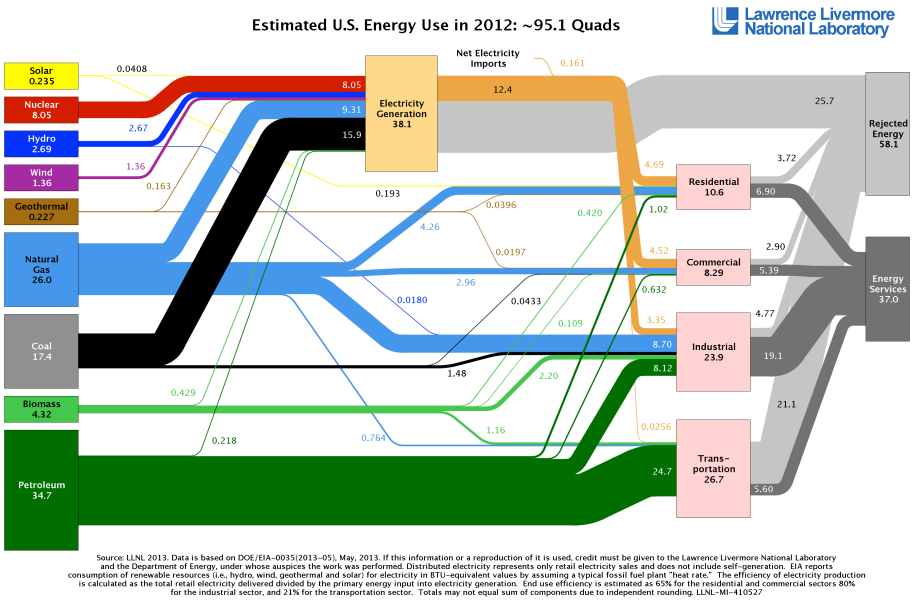


Electromagnetic Radiation to Electric

- Solar cell (photovoltaic cell, PV cell)
  - Photons knock loose electrons in silicon
  - Combination of n-p layer induces drift current

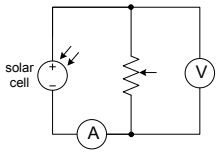


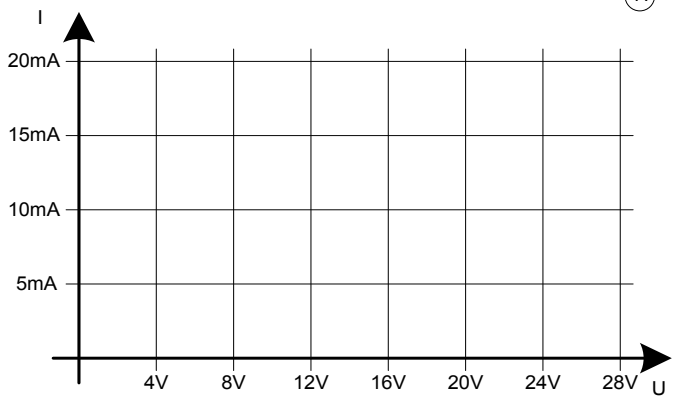
Energy Flow in U.S.



Demo

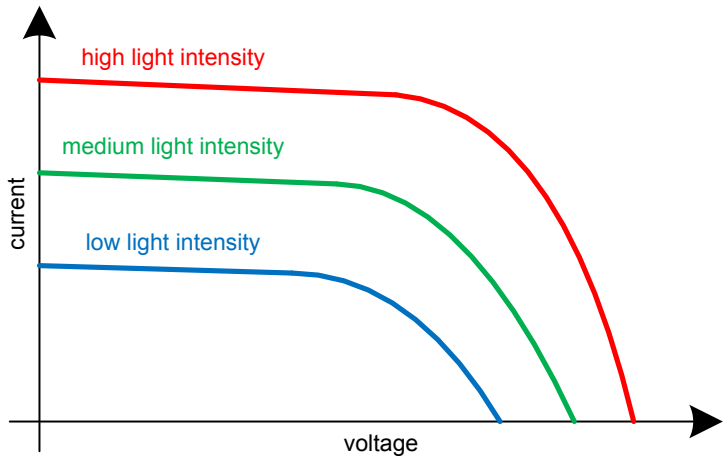
- Measurement of current and voltage of real solar cell
  - Potentiometer to "move along characteristic cure"





Solar Cell: Voltage and Current

- "Characteristic curve" of solar cell
  - Relationship between current and voltage
  - Curve depends on light intensity, temperature, etc.



System Optimization

- How to get maximum power out of the solar cell?

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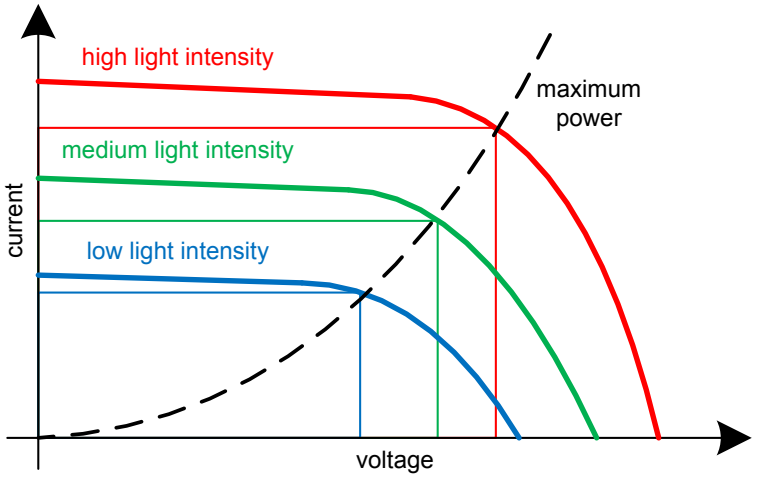
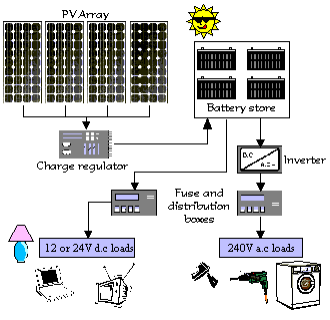
  - Power is P=I·V
  - Maximize "P area" under curve



System Optimization

- Problem: optimal operation point changes with conditions
  - "Maximum power point tracker"
    - » DC-to-DC converter
    - » DC voltage on solar cell side: voltage of optimal operation
    - » DC voltage for battery charging
- Typical installation:



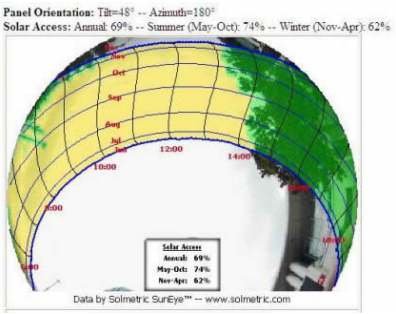
Solar Installation

- Example installations:

- Amount of solar exposure determines effectiveness of system
  - How to find best location?

Meet a UMass EE Alumnus

- Willard MacDonald (EE'94)
  - President and CEO of Solmetric
- Product: SunEye
  - Embedded device to measure and compute solar exposure
    - » Camera captures sky view
    - » Location determines sun's path



Courses in ECE Curriculum

- ECE 211 – Circuit Analysis I
- ECE 212 – Circuit Analysis II
- ECE 323 – Electronics I
- ECE 324 – Electronics II
- ECE 597D – Power Systems

Upcoming…

- Next Wednesday: power grid
  - Power distribution
- Moodle quiz