



University of  
Massachusetts  
Amherst

## Lecture 5–Power Generation

ECE 197SA – Systems Appreciation

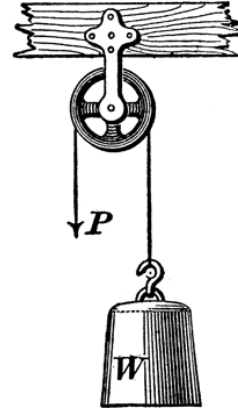
## Electric Power

- 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



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## Activity

- What are sources of energy?

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## 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

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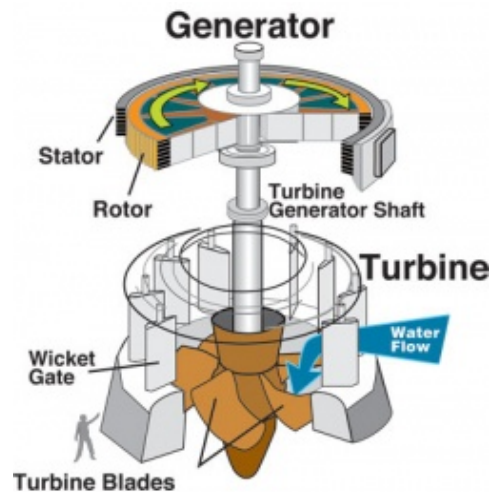
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mechanical	lever	brakes	dynamo	synchrotron	matches	particle accelerator
thermal	steam turbine	heat exchanger	thermocouple	hot objects	blast furnace	supernova
electric	electric motor	resistor	transformer	light-emitting diode	electrolysis	synchrotron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

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# Mechanical to Electric

- Hydroelectric turbine



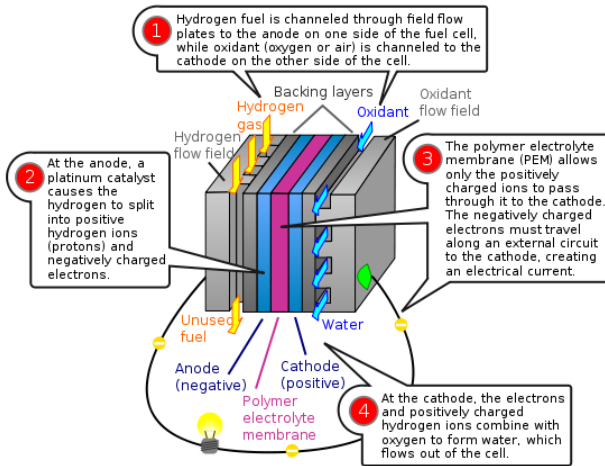
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# Chemical to Electric

- Fuel cell
  - Chemical reaction directly generates current

## Proton exchange membrane fuel cell

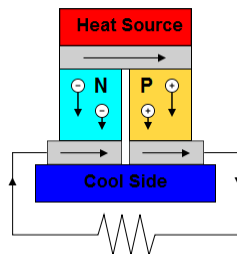


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# Thermal to Electric

- Thermocouple
  - Thermoelectric effect used to generate voltage

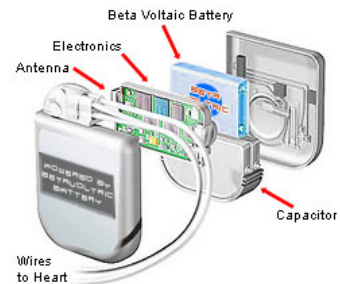
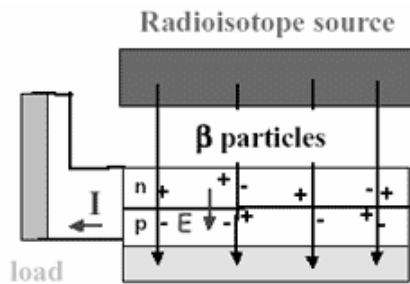


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# Nuclear to Electric

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

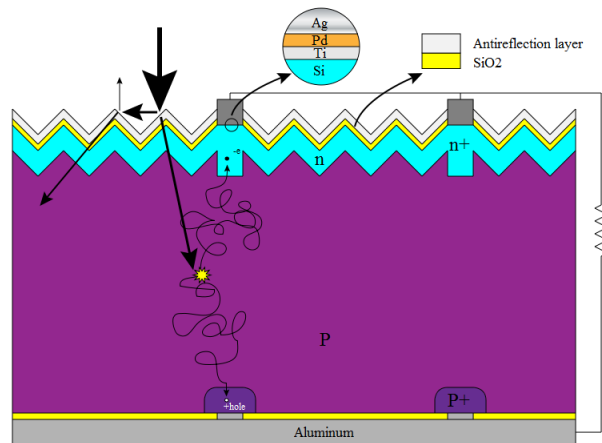


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# Electromagnetic Radiation to Electric

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



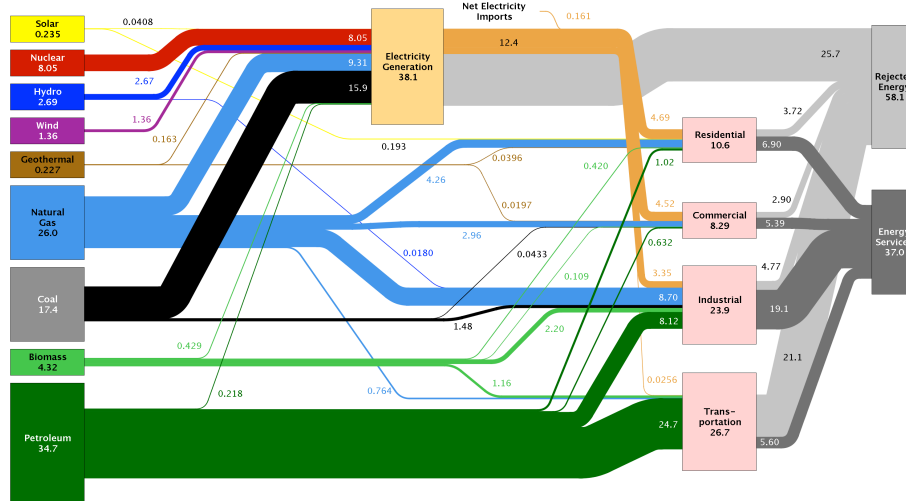
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# Energy Flow in U.S.

Estimated U.S. Energy Use in 2012: ~95.1 Quads

Lawrence Livermore National Laboratory



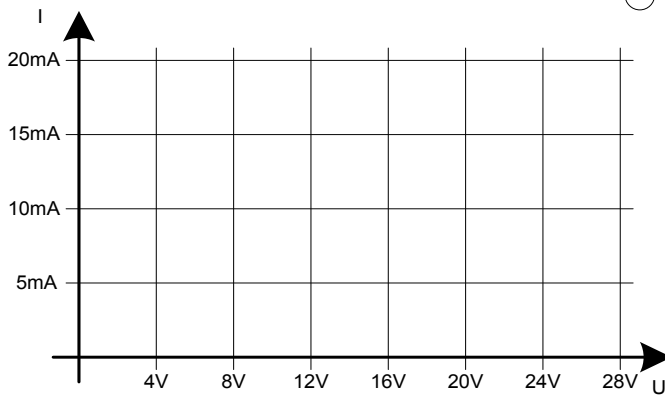
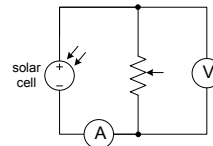
Source: LLNL 2013. Data is based on DOE/EIA-0855(2013-05), May, 2013. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 92% for the residential and commercial sectors, 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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## Demo

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

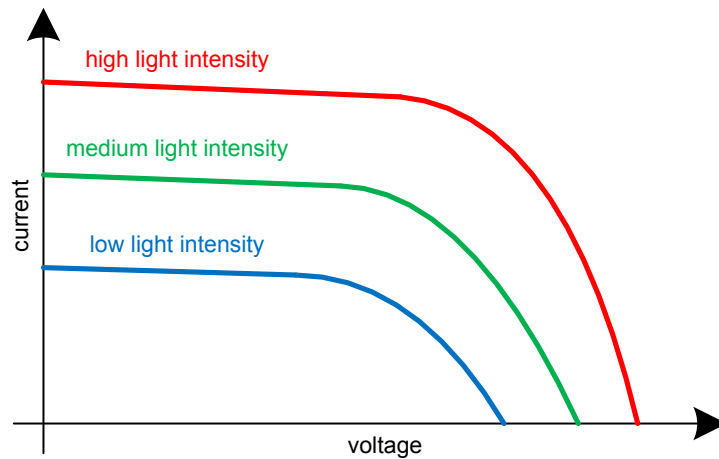


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## Solar Cell: Voltage and Current

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



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## System Optimization

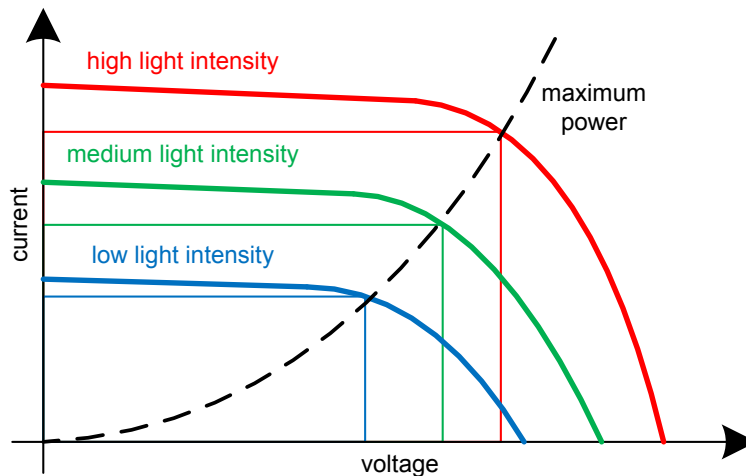
- How to get maximum power out of the solar cell?

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# System Optimization

- How to get maximum power out of the solar cell?
  - Power is  $P=I \cdot V$
  - Maximize "P area" under curve

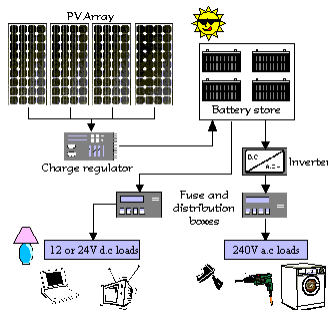


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# System Optimization

- 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:



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# Solar Installation

- Example installations:



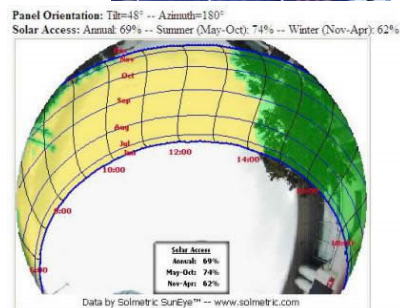
- Amount of solar exposure determines effectiveness of system
  - How to find best location?

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# 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



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## 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

