Lec #12: finish Thermal Energy. start E&M

LAST: Thermal Energy. II.

- Phase Transitions and Latent Heat
- Heat Transfer (conduction, convection, radiation)

TODAY: Heat Engines; start Electricity & Magnetism

- Thermodynamic Efficiency
- Heat Engines
- Electric and Magnetic Forces and Fields
- Electromagnetic Induction

NEXT: Electrical Energy. II. (Chapters 10,11)

- Electricity and Circuits
- Introduction to the Electric Power Grid

NO CLASS NEXT WEDNESDAY

Thermodynamic Efficiency

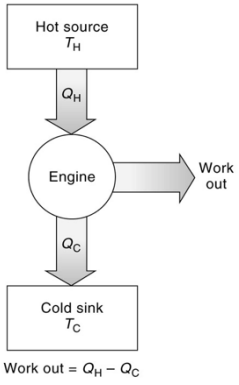
Efficiency = 100%x(useful energy out)/(available energy)

- What is "useful" energy (or work) out?
- What is "available" energy in?
- For a heat engine, useful work out is always *less than* the available energy input

Maximum ("Carnot") efficiency:

Maximum Efficiency = 100% x $(T_H - T_C) / T_H$

- caution: must use absolute temperature scale!
- $T_H > T_C$ so ratio is always <1



Examples:

T_H	T_C	η
1000	373	63%
813	293	64%
4000	300	93%
OTEC...25 C	5 C	6%

but what happens at 4000 degrees?

how low can T_C go?

how high can T_H go?

Energy Conversion Efficiency

- Efficiency = 100% x (useful energy out) / (available energy in)
- seldom, if ever, 100%
- Net efficiency = **product** of individual efficiencies
- Chain that is weaker than its weakest link!

Table 3.1 EFFICIENCIES OF SOME ENERGY CONVERSION DEVICES AND SYSTEMS

Device	Efficiency
Electric generators (mechanical → electrical)	70–99%
Electric motor (electrical → mechanical)	50–90%
Gas furnace (chemical → thermal)	70–95%
Wind turbine (mechanical → electrical)	35–50%
Fossil fuel power plant (chemical → thermal → mechanical → electrical)	30–40%
Nuclear power plant (nuclear → thermal → mechanical → electrical)	30–35%
Automobile engine (chemical → thermal → mechanical)	20–30%
Fluorescent lamp (electrical → light)	20%
Incandescent lamp (electrical → light)	5%
Solar cell (light → electrical)	5–28%
Fuel cell (chemical → electrical)	40–60%

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Ideal Gas Law

- Pressure = |**Force**| /Area (not a vector)
- "ideal gas": energy exchange dominated by elastic collisions

  equation of state:

  Pressure x Volume = k x Temperature

  (k= Boltzman's constant)
- solids and liquids (and some gasses) have different equations of state; related to potential energy of bonds, elasticity of collisions, etc.

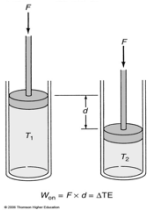
Table 4.3 EXAMPLES OF HEAT ENGINES

Vapor or Rankine cycle

Steam engine (electrical power plant, old train locomotive)
Refrigerator, heat pump (using Freon)

Gas cycle

Internal combustion: Otto, Diesel cycles (automobiles, trucks)
External combustion: gas turbine (airplanes, electrical power plant), Stirling cycle



howstuffworks.com

(heat->work)	(work->heat)
steam engine	air conditioners
gasoline engine	dehumidifiers
diesel engine	heat pumps
gas turbine	refrigerators

Examples of Electromagnetic Induction

- Electrical Current --> Magnetic field
  - compass needle deflection
  - electromagnet
  - planetary magnetic fields (where is the current?)
- Changing Magnetic field --> Current
  - generator
  - motor
- Lenz's Law
  - "Will of Landru" demo
  - jumping rings