AST1002

Key Concepts for Astronomy

Chapter 4
A Universe of Matter and Energy

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Matter and Energy in Everyday Life

- Matter: Stuff … can be handled or put in a box; made up of atomic particle (atoms, electrons, protons, neutrons)
- Energy: What makes matter do things
  - Measured in
    - ***Calories*** (an adult "burns" about 2500 per day)
    - or ***joules*** (4000 joules = 1 Calorie)

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Matter and Energy in Everyday Life

- Energy: What makes matter do things
  - Kinetic energy: energy of motion
  - Potential energy: stored energy
    - Gravitational potential energy
    - Chemical potential energy
    - Electrical potential energy
  - Radiative energy
- Energy is frequently converted from one form to another

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A Scientific View of Energy

- Kinetic energy
  - $E=\frac{1}{2}mv^2$

  if m=mass (kilograms),
  v=velocity (meters per second),

  Then E is in joules


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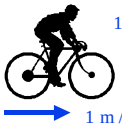
100 kg
1 m/s

100 kg
2 m/s

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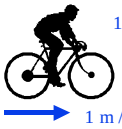
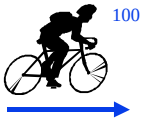

100 kg
1 m/s
50 joules

100 kg
2 m/s
200 joules

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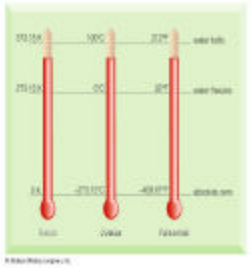
A Scientific View of Energy

- Temperature scales
  - Fahrenheit
  - Celsius
  - Kelvin



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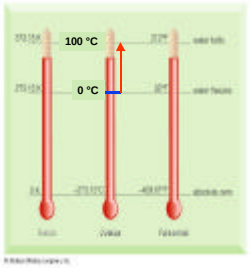
A Scientific View of Energy

- Temperature scales
  - Fahrenheit
  - **Celsius**
  - Kelvin
- Defined by
  - Zero point
  - Scale



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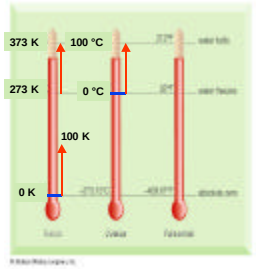

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A Scientific View of Energy

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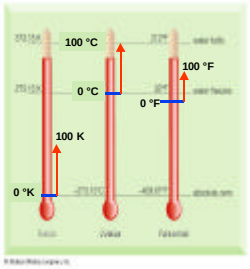

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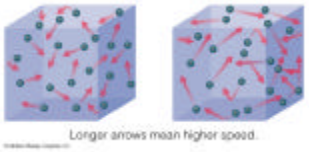
A Scientific View of Energy

- Temperature
  - The average kinetic energy of the atoms in the material or gas
  - Related to the average speed ($v \propto \sqrt{T}$)



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A Scientific View of Energy

- Temperature
  - The average kinetic energy of the atoms in the material or gas
  - Related to the average speed ($v \propto \sqrt{T}$)
- Why use the Kelvin temperature scale?
  - Hint … how does $\sqrt{T}$ behave at cold temperatures? At what T should v=0 (all motion stopped)?

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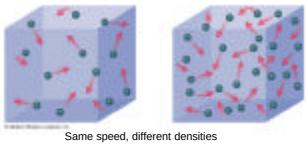
A Scientific View of Energy

- Heat
  - Related to the total thermal energy so it depends on both
    - Temperature and
    - Density (number of atoms)



Same speed, different densities

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A Scientific View of Energy

- Heat
  - Related to the total thermal energy so it depends on both
    - Temperature and
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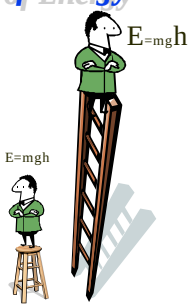
A Scientific View of Energy

- Potential Energy
  - Gravitational Energy

The amount of gravitational potential energy depends on the mass, the strength of gravity, and the height E=mgh



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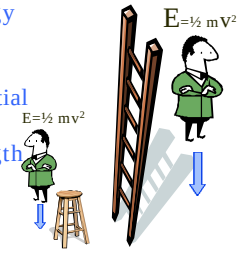

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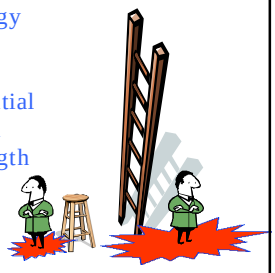

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A Scientific View of Energy

- Potential Energy
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The amount of gravitational potential energy depends on the mass, the strength of gravity, and the height

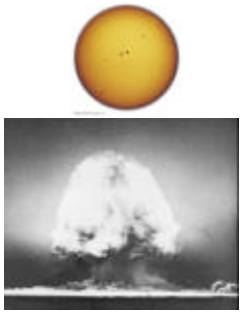
AST1002 C4 p 72-73

A Scientific View of Energy

- Potential Energy
  - Mass-energy
    $E=mc^2$

    E=energy (joules)
    m=mass (kilograms)
    c=constant (speed of light; $3x10^8$ m / s)

    so 1 gram contains
    $9x10^{13}$ joules
    (225 billion Calories)
  - Conservation of Energy



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The Material World

- Solid
- Liquid
- Gas
  - Molecules
  - Atoms
    - Electrons
    - Protons
    - Neutrons

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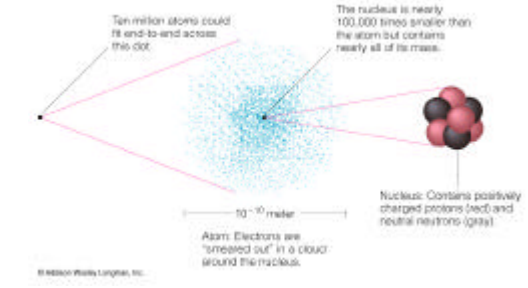
The Material World



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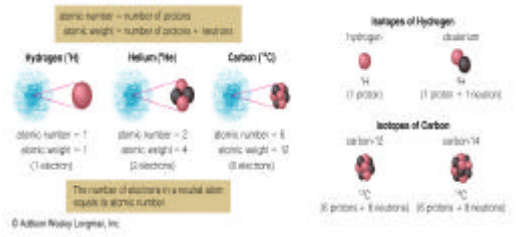
The Material World



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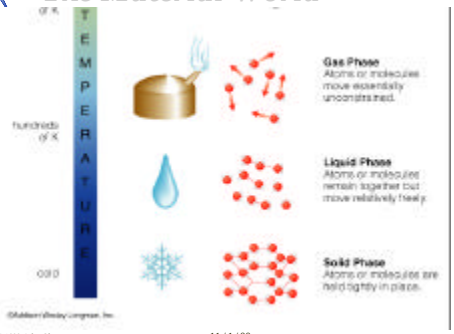
The Material World



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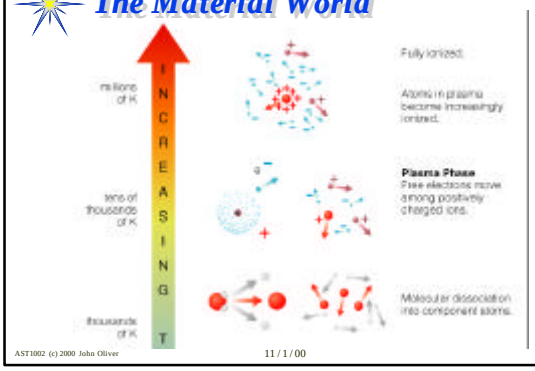
The Material World



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The Material World

Atoms can be ionized multiple times if they have more than one electron: higher T means more ionization

Atom	# protons	# electrons	
Hydrogen	1	1	H^0,H^+
Helium	2	2	He^0,He^+,He^{+2}
Oxygen	8	8	O^0,O^+… O^{+8}
Iron	26	26	Fe^0,Fe^+… Fe^{+26}

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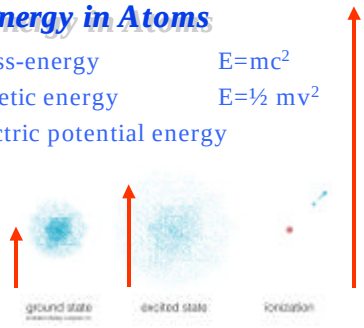
Energy in Atoms

- Mass-energy $E=mc^2$
- Kinetic energy $E=½\ mv^2$
- Electric potential energy



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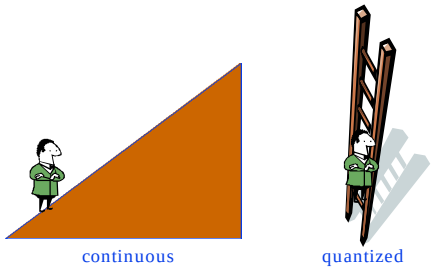
Energy in Atoms

- Electric potential energy is *quantized*



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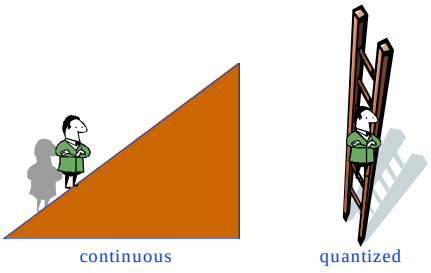

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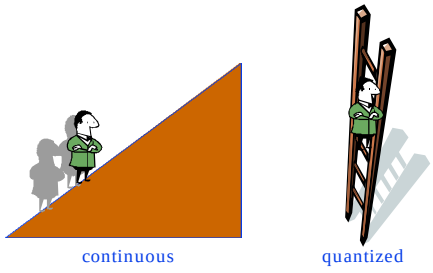

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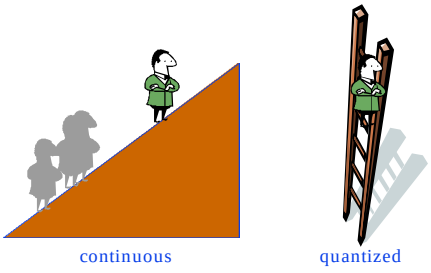

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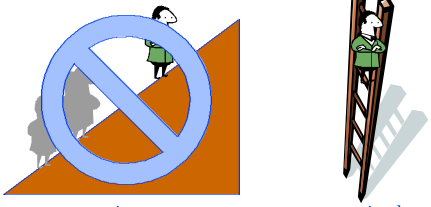

continuous quantized

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Energy in Atoms

- 1 electron-volt (eV) = 1.6 x 10^{-19} joule

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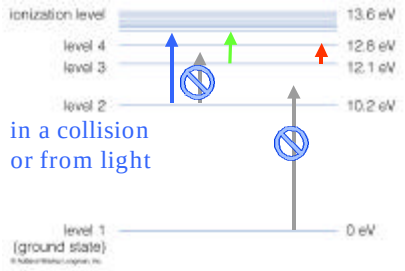
Energy in Atoms

- Energy can be absorbed



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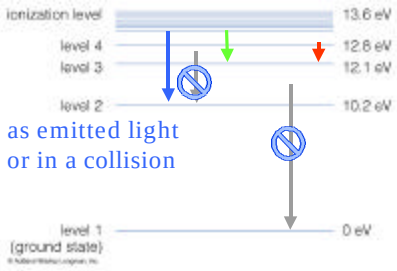
Energy in Atoms

- Energy can be given off as well



Questions and/or Comments?

Let me know at oliver@astro.ufl.edu

or visit http://www.astro.ufl.edu/~oliver/