Energy and Work

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- What is energy?
- Kinds of energy
- Energy sources
- Kinetic energy
- Work
- Work-energy theorem
What’s In These Slides

- Some basic definitions and examples
  - More details will be worked out on the board, and should be available in BlackLightning notes
What is Energy

• We all know this intuitively
  □ You need “energy” to move objects
    ➤ e.g. burn gasoline to move cars
    ➤ Calories to move our body parts
    ➤ Gas or electric energy to heat up food (and we will talk about temperature as a measure of motion of the molecules)
  □ So we will use this intuition to define a physical quantity more formally
    ➤ But add some constraints to make the quantity more fundamental
What is Energy (cont.)

• **Webster definition:**
  
  » A fundamental entity of nature that is transferred between parts of a system in the production of physical change within the system and usually regarded as the capacity for doing work

  □ **Great, so need to define work**
  
  » We will do this formally in a minute, but for now, we can define work as a scalar quantity which measures the effect of a force on motion of an object

• **Alternative definition**
  
  » A measure of ability to produce heat
More Physics Definitions

- We want to define a *scalar* quantity that
  - Is relation to motion (or ability to cause motion)
    - E.g. for a moving object, increases with speed
  - Is additive for a collection of objects
    - I.e. $E_{\text{tot}} = E_1 + E_2 + \ldots + E_n$
  - Can be converted from one form to another by forces
    - Here is where work comes in
  - And is conserved for all fundamental processes
    - Formally, this is called an integral of motion
Three Kinds of Energy

• **Kinetic energy**
  - Scalar quantity describing motion
    - $K = \frac{1}{2}mv^2$

• **Potential energy**
  - Scalar quantity describing potential to move (itself or other objects)
    - Gravitational potential energy

• **Mass**
  - Einstein’s famous
    - $E = mc^2$
    - For example reaction $e^+ + e^- \rightarrow 2\gamma$ yields energetic photons
Energy Transfer

- **Mechanical energy transfer**
  - Work
    - Acts on *macroscopic* objects, this is what we will care about from now until April

- **Thermal energy transfer**
  - Heat
    - Acts on *microscopic* objects
Everyday Energy Sources

- **Chemical energy**
  - Potential energy due to interaction of electrons with nuclei
  \[ 2H_2 + O_2 = 2H_2O + \text{heat} \]

- **Nuclear energy**
  - Potential energy of interaction between protons and neutrons

- **Electrical energy**
  - Kinetic energy of moving electrons or potential energy of electrons in electric fields

- **Solar energy**
  - Kinetic energy of moving photons

- **Wind, hydro energy**
  - Kinetic energy of moving fluids
## Some Energy Sources

<table>
<thead>
<tr>
<th>1g of</th>
<th>Energy (kJ)</th>
<th>Energy (Cal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>42</td>
<td>10</td>
</tr>
<tr>
<td>TNT</td>
<td>2.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Chocolate chip cookie</td>
<td>21</td>
<td>5</td>
</tr>
</tbody>
</table>

Courtesy R. Muller
Energy Conservation

• Fundamental property of nature
  - Energy does not disappear and does not appear out of nowhere
  - It only gets transformed
    - Demo with the bowling ball
Work-Energy Theorem

• Free-fall example