Lecture 10 Notes

1. Temperature Scale
   - Room temp of 68°F
   - \( T = \frac{68-32}{212-32} = 0.20 \)
   - \( T = 20°C \)

2. Thermal Expansion
   - Linear coefficient \( \alpha \)
   - \( \frac{\Delta L}{L} = \alpha \Delta T \)
   - \( \frac{T}{T+\Delta T} = \frac{1}{1+\alpha \Delta T} \)

   Examples: buckling sidewalk,
   bridge construction

   Concrete: \( 12 \times 10^{-6} / °C \)
   Brass: \( 19 \times 10^{-6} / °C \)
   Steel: \( 11 \times 10^{-6} / °C \)

   Volume expansion is 3x linear

   \( \frac{\Delta V}{V} = (3\alpha) \Delta T \)
As oceans "heat up", volume expands and sea levels rise.

Conduction, Convection, Radiation

(3) Heat transfer by conduction

\[ \Delta Q = A \cdot k \left( \frac{T_H - T_C}{L} \right) \]

\[ = A \left( \frac{T_H - T_C}{R} \right) \]

\[ k = \text{thermal conductivity, Watts/m/C} \]

\[ \Delta C = \Delta K \Rightarrow \Delta N \text{ Kelvin} \]

\[ R = \frac{L}{k} \left( F^2 \cdot (F^\circ) \cdot \text{hour} \right) / \beta T \circ = 0.176 \frac{m^2 \cdot C^\circ}{W} \]
R-value added: \( R_{eff} = R_1 + R_2 \)

<table>
<thead>
<tr>
<th>Material</th>
<th>( k )</th>
<th>Metal Conduct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>235</td>
<td>( \text{with heat} )</td>
</tr>
<tr>
<td>Cu</td>
<td>401</td>
<td>Electricity</td>
</tr>
<tr>
<td>fiberglass</td>
<td>0.043</td>
<td></td>
</tr>
<tr>
<td>air</td>
<td>0.026</td>
<td></td>
</tr>
</tbody>
</table>

4. Radiation

\[
power = 5 \cdot E \cdot A \cdot \left[ T(\text{Kelvin}) \right]^4
\]

\( E \) "sigma" universal constant
Stephan-Boltzmann

\( A \) surface area of object
\( E \) emissivity \( 0 < E < 1 \)

<table>
<thead>
<tr>
<th>Material</th>
<th>( E )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td>0.16</td>
</tr>
<tr>
<td>Polished silver</td>
<td>0.03</td>
</tr>
<tr>
<td>Brick</td>
<td>0.85</td>
</tr>
<tr>
<td>Skin</td>
<td>0.96</td>
</tr>
<tr>
<td>Water/ice crystal</td>
<td>0.98</td>
</tr>
<tr>
<td>Snow</td>
<td>0.85</td>
</tr>
</tbody>
</table>
6. Greenhouse effect:

- Transparency of glass depends on wavelength of radiation.
- Example: heating of car
  
  - Glass
  - Infrared
  - Sunlight (visible)
  - Fabric of car seat

- Fabric heated by sunlight re-radiates in the infrared.
- Glass allows sunlight to penetrate (is transparent) but reflects infrared.

7. Heat capacity:

- Temperature change ($\Delta T$) due to transfer of heat ($Q$) depends on mass and composition of material

\[
\Delta Q = C \times \text{(mass)} \times \Delta T
\]

- Specific heat ($C$) is measure of heat capacity, or increase in temperature with absorption of heat.

- $C$ is measured in $\text{cal / g°C}$, $\text{J / kg K}$.
<table>
<thead>
<tr>
<th>Material</th>
<th>( C(\text{Cal/gC}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>0.215</td>
</tr>
<tr>
<td>ice</td>
<td>0.50</td>
</tr>
<tr>
<td>CO</td>
<td>0.092</td>
</tr>
<tr>
<td>water</td>
<td>7.00</td>
</tr>
<tr>
<td>air</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Microscopic picture:

Internal energy gets distributed equally between degrees of freedom

\[
\text{Translational} = 3 \times \left( \frac{1}{2} kT \right)
\]
\[
\text{Other} = n \times \left( \frac{1}{2} kT \right)
\]

Fluid analogy:

\( \Delta Q \) 

\( \Delta T \)

\# broken \( \propto \) degrees of freedom, \( B \) has greater heat capacity
6. First Law of Thermodynamics

Increase in internal energy

\[ \Delta Q = \text{heated absorbed} + \text{work done on the system} \]

Change in internal energy

\[ \Delta Q = \Delta Q + \Delta W \]

Where \( \Delta Q > 0 \) absorbed
\( \Delta Q < 0 \) removed
\( \Delta W > 0 \) done on system
\( \Delta W < 0 \) done by system

Compression of gas by piston:

\[ \Delta Q = \text{Force} \times \text{Compress} \quad W > 0 \]

\[ W = \text{Force} \times \Delta x \]

T of gas increases

Expansions of gas by piston \( W < 0 \)

\[ \Delta Q = \text{Force} \times \text{Area} \]

T of gas decreases