L 16 Heat and Thermodynamics [1]

- What is temperature?
- How is it measured?
- What is heat?
- What is the difference between heat and temperature?
- Applications: engines, refrigerators, air conditioners, human body, electric power production systems
- It's all about how ENERGY is used.

World and US energy Consumption

Temperature is not the whole story!

- Cake and pan just taken out of a 400° oven.
- Both are at 400°
- You can touch the cake, but not the pan!
- You can handle toast right out of the toaster
- You can eat the pie crust, but not the filling.

Drilling or grinding

- After drilling into a piece of metal, the drill bit is very hot
- The metal being ground also gets hot
- You can also get the bit or the metal hot by placing it in a torch
- Is there a difference in the outcome?

Engines

- Any device which uses heat to do work
- Steam engine, internal combustion engine

Burn fuel → boil water (steam) → push piston (work)
Human engine

• The human body is an engine.
• Food in → metabolism → work out
• Energy in → BED ENGINE → Energy out
• We are all subject to the laws of thermodynamics

Internal energy & Temperature

• All systems have internal energy
• The internal energy is the sum of the energy of all the molecules in the system
• For example- in a gas the molecules are in random motion – each molecule has kinetic energy (energy of motion = ½ m v²)
• If we add up all the kinetic energies of all the molecules we get the internal energy

Energy transfers

• All systems (living organisms and mechanical) are continually exchanging energy with other systems or their environment.

Energy transfer examples

• Ice melts in water
• water boils
• steam condenses to water
• Water → ice in freezer
• Pop cools in refrigerator
• The sun warms you on an autumn day
• Water is circulated through your car engine to maintain a steady temperature

Thermodynamics

• Is the study of heat energy and its transformation into mechanical energy.
• Is a set of a few basic empirical rules (derived from observation) that place limits of how these transformations can occur, and how efficiently they can be carried out.

Engines

Efficiency = \( \frac{\text{Work out}}{\text{Energy in}} \)

If we convert all of the energy taken in to work the efficiency would be 100%
Laws of thermodynamics in a nutshell

I. You can't get more work out than the energy you put in (conservation of energy).

II. You can't even get as much out as you put in (engine efficiency cannot be 100%).

Energy conversion

30 years ago almost 50% of energy was lost as waste heat. Things are improving!

Temperature measurement

- We use the fact that the properties of materials change with temperature
- For example:
  - Metals expand with increasing temp
  - Length of liquid column expands
  - Electrical resistance changes
  - Pressure of a gas increases with temp
  - Infrared emission from objects changes color

Can we trust our senses of hot and cold?

Will both fingers feel the same temperature when they are put in the warm water?

Length of a mercury column

- The length of the Hg column increases with temperature
- How is the thermometer calibrated?
  - temperature scales
    - Fahrenheit
    - Celsius
    - Kelvin
**Temperature scales**: based on freezing and boiling points of water

- **Celsius scale**
  - Freezing point: 0°C
  - Boiling point: 100°C
- **Fahrenheit scale**
  - Freezing point: 32°F
  - Boiling point: 212°F

**Centigrade & Fahrenheit scales**

- Scales are offset (0°F is not 0°C)
- Celsius scale is compressed compared to the Fahrenheit scale
- \(1°C = \frac{180}{100} = \frac{9}{5}°F\)
- Conversion formulas:
  - \(T_C = \frac{5}{9} \times (T_F - 32)\)
  - \(T_F = \frac{9}{5} \times T_C + 32\)

**Examples**

1) What is the temperature in C if the temperature is 68°F?
   \[T_C = \left(\frac{5}{9}\right) \times (68 - 32) = \left(\frac{5}{9}\right) \times 36 = 20°C\]

2) What is the temperature in F if the temperature is -10°C?
   \[T_F = \left(\frac{9}{5}\right) \times (-10) + 32 = -18 + 32 = 14°F\]

**Absolute zero – as cold as it gets!**

- There is nothing particularly significant about 0°C or 0°F.
- Is there a temperature scale where 0 really is ZERO? It doesn’t get any colder than this!
- YES– It is called the **KELVIN** scale.
- At zero Kelvin, all molecular motion stops.
- We can see this from the behavior of gases, where pressure decreases with temperature.

**Kelvin scale**

- \(T_K = T_C + 273.15°C\)
- One degree K = one degree C
- There are NO negative Kelvin temperatures, zero is the minimum.

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**Absolute zero**

- As a gas is cooled, its pressure decreases. If we imagine continuing to cool it, the P vs T plot for all quantities of gas extrapolate to -273.15°C.
- This is absolute zero!