Temperature

- relative measure of hotness or coldness

Heat

- energy transferred based on temperature difference

Thermal Contact

- condition in which heat may be transferred between objects.

Thermal Equilibrium

- condition in which heat is not transferred between objects.

Thermodynamics

- study of heat transfer.

Zeroth Law of Thermodynamics

- Under the conditions of thermal equilibrium no heat transfer will occur.

* Thermal equilibrium occurs when the temperature of any ~~two~~ given objects in thermal contact are the same.

* Main Idea *

If Temp. A = Temp B

and

Temp B = Temp C

Then

Any thermal contact between A, B, or C will result in thermal equilibrium state.

Temperature Scales

Kelvin

- based on absolute zero*
- degree size is equivalent to Celsius

Celsius

- based on boiling (100C) and freezing (0C) points of water
- degree size equivalent to Kelvin

Fahrenheit

- based on body temp. and lowest achievable laboratory temp. at time of inception (Early 1700's).
- different degree size than Celsius and Kelvin

* Note: Absolute zero is the lowest possible temperature.

Temp. Conversions

$$T_k = T_c + 273$$ Celsius → kelvin

$$T_F = \frac{9}{5} T_c + 32$$ Celsius → Fahrenheit

T_k = kelvin temp.

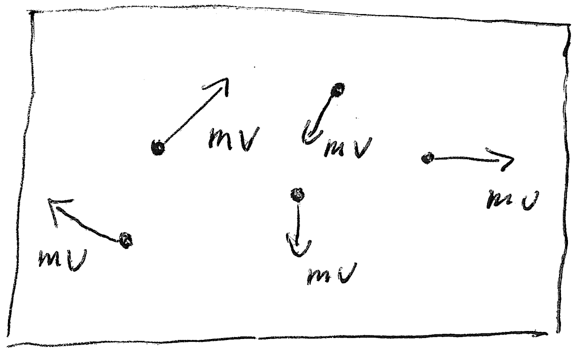
T_c = Celsius temp.

T_F = Fahrenheit temp.

Note: Solve the equation for the desired temp. scale to use in your particular situation. This is more useful than writing an equation for any possible conversion.

Kinetic Molecular Theory and Temperature

Temperature is associated with random molecular motion.



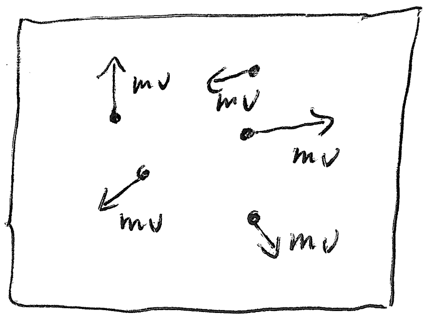
Gas Sample

↑ Temp ⟶ ↑ $|\bar{v}|$ for molecules

(temp increase) (average speed increases)

Thermal Expansion

Temperature is related to the amount of space occupied by a given object.



Gas Sample

$\uparrow T \rightarrow \uparrow |\bar{v}| \rightarrow \uparrow$ # collisions with boundary

also

an increased speed is accompanied by a larger momentum

Recall

$$F \Delta t = \Delta p$$

So if Δp increases

F most also increase

for a given collision time

If the boundary can't balance the increased force from the collissons, it will move.

* This is a model for gases, but it will assist in the understanding of more complex behaviors in liquids and solids. *

Linear Expansion

- change in length associated with temp. change

$$\Delta L = \alpha L_0 \Delta T$$

ΔL = change in length

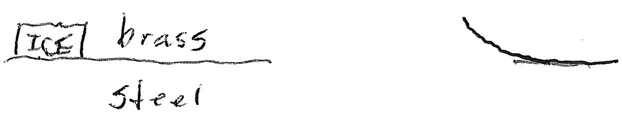
α = coefficient of linear expansion (material dependent)

L_0 = initial length

ΔT = change in temp.

Demo: Bimetallic Strip

Brass expands more



Brass shrinks more

Area Expansion

- change in area associated with temp. change.

$$\Delta A = 2\alpha A_0 \Delta T$$

(approximation reasonable in most cases)

*Demo: ball & ring

Volume Expansion

- change in volume associated with temp. change

$$\Delta V = 3\alpha V \Delta T$$

(approximation reasonable in most cases)

$$\Delta V = \beta V \Delta T$$

β = coefficient of volume expansion

Heat and Mechanical Work

Heat (Q)

- energy transfer due to temp. difference

- Units: kilocalorie (kcal)

  Joule (J)

  1 kcal = 4186 J

  British thermal Unit (BTU)

  1 BTU = 0.252 kcal = 1055 J

Specific Heat

Heat Capacity (C)

$$C = \frac{Q}{\Delta T}$$

Q = heat (J)

T = temp (C)

C = heat capacity $\left(\frac{J}{C}\right)$

- Rate of heat transfer per temperature difference
- always positive like speed.
- independent of material

adding heat to system

Q - positive

ΔT - positive

removing heat from system

Q - negative

ΔT - negative

Specific Heat (c)

- heat capacity weighted by ~~material~~ mass
- this value can be found in a table for a specific material.

$$c = \frac{Q}{m \Delta T}$$

m = mass (kg)

Q = heat (J)

ΔT = temp. change (C) or (K)

c = specific heat

* Amount of heat required to change the temperature of a given mass by 1°. *

Heat Transfer Mechanisms

Conduction

- transfer mechanism for heat where heat flows directly from one material to another.
    - materials are in thermal contact and physical contact.
    - similar to electrical conduction
        - materials with good electrical conduction are usually good thermal conductors.

$$Q = kA\left(\frac{\Delta T}{L}\right)t$$

t = time (s)

ΔT = temp. change (C)

L = thickness (m)

A = surface area (m^2)

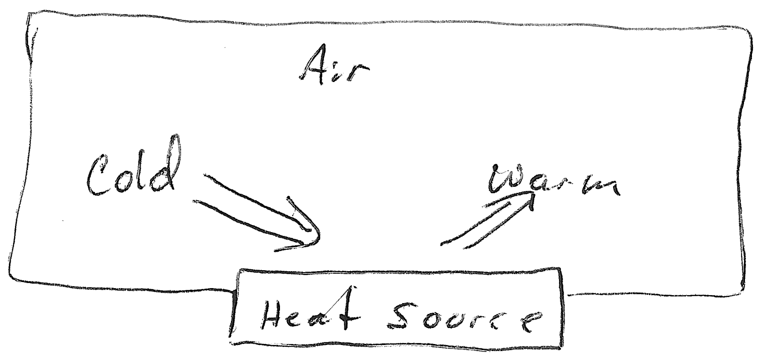
K = conductivity constant

Convection

- heat transfer via movement of mass

- Most commonly associated with air that is heated unevenly.

- warm air is pushed up by more dense cool air



* Weather patterns are the result of this on a global scale and local/regional scale

* Ocean currents are the result of this on a global scale

TWO cases →
* materials are in thermal and physical contact (air heated by electric heater)
* materials in thermal contact only
  Sun and Ocean Water

Radiation

- release of energy in the form of electromagnetic waves

  (usual case)

- All objects emit radiation

  - can be visible in the form of light

- depends on surface Area and how well the object can absorb/~~transm~~ emit photons.

Radiated Power Equation

$P = e\sigma A T^4$ $\quad T = \text{temp.}(K)$

e = emissivity number from 0 to 1 indicating how well an object absorbs/emits photons

* dark colors tend toward 1
light colors tend toward 2

$\sigma = 5.67E{-8} \frac{W}{m^2K^4}$

A = surface area (m^2)

Recall : $P = \frac{E}{t}$

in our case

$P = \frac{Q}{t}$ ↗ Heat, ↘ time

time rate of heat transfer.

Net Radiated Power

$$P_{Net} = e\,\sigma A\left(T^4 - T_s^4\right)$$

* Accounts for absorbed and radiated energy.

* thermal contact does not require physical contact!

Ex Sun - Earth

Sun warms earth but does not touch earth.