Physics 101

Lecture 34

Monday, March 29, 2004

Topics: Conduction, Convection, Radiation

Heat capacity and specific heat.

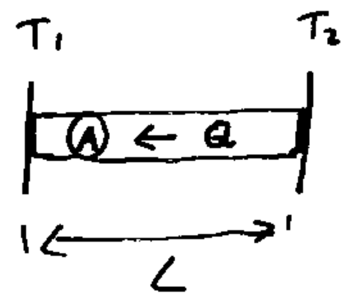
Ideal gas

Ref: 16-5, 6, 17-1, 2.

- Conduction ⇒ No mass transport.

  Heat flow due to interactions among molecules and atoms.

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



Q — amount of heat in Jouls.

k — Thermal conductivity.

ΔT — Temperature difference $\Delta T = T_2 - T_1$.

A — cross section

L — Length of rod.

t — time in sec.

Table 16-3. for k: p.519. copper is a better heat conductor than gold.

- convection

  — due to mass transport.

  e.g.: forced hot air.

  complicated — No quantitative calculation in this course.

- Radiation (Stefan-Boltzmann Law)

  — due to electromagnetic wave.

  (No physical contact)

  Radiated power: (

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

  $\sigma = 5.67 \times 10^{-8}\ W/m^2 \cdot K^4$. (Stefan-Boltzmann constant)

  $0 \le e \le 1$ — emissivity.

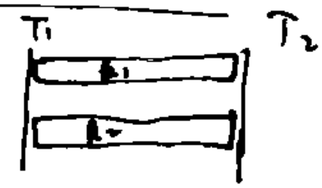
  for black body (ideal): $e = 1$

  perfect emitter

- conduction

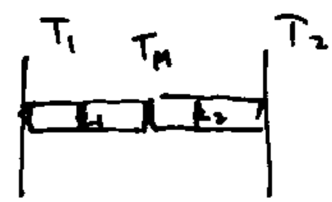
  * Parallel rods.

    $Q_{Total} = Q_1 + Q_2$



  * series rods:

    $Q_1 = Q_2 = Q_{Total}$.



e.g.: Fall 2002. Final. exam. #22. (Next).

- Heat Capacity. — C

Q - Heat absorbed by the object.

For an object: $\Delta T \propto Q$.

It's heat capacity: $C = \dfrac{Q}{\Delta T}$ (depends on mass)

$$\Delta T = \frac{Q}{C}, \quad Q = C \cdot \Delta T$$

The larger the heat capacity,
the harder to change the temperature.

Sign of Q: if $\Delta T > 0$, T increases.
Then $Q > 0$, Heat added to system.

if $\Delta T < 0$, T decreases,
Then $Q < 0$, Heat removed from system.

- Specific heat — c

For a ~~[illegible]~~ substance

$$c = \frac{Q}{m \cdot \Delta T} = \frac{C}{m}.$$ (independent of mass)

Values of specific heat for different materials: Table 16-2. p. 516.
example: 16-5. p. 515.

- Ideal Gases (you learn this in more details in chemistry)
  - — No interaction between molecules.

$$\frac{PV}{T} = \text{const.}$$

e.g.: when V is fixed, $T \uparrow \Rightarrow P \uparrow$.

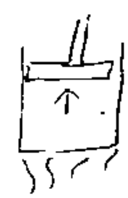
e.g. when T is fixed, $\cancel{P \uparrow \Rightarrow V \downarrow}$

$V \downarrow \Rightarrow P \uparrow$.

Compressor.

e.g. when P is fixed. $T \uparrow \Rightarrow V \uparrow$

steam engine.



$$\frac{PV}{T} = Nk.$$

N — Number of molecules.

$k = 1.38 \times 10^{-23}$ J/k.

Boltzmann Constant.

OR.

$$\frac{PV}{T} = nR.$$

n — number of moles

$R = 8.31$ J/mol·K.

Universal gas constant.

$$N = n N_A$$

N_A — Number of molecules in a mole.

$N_A = 6.022 \times 10^{23}$ Avogadro's number.

- Kinetic Theory.

Model — Many identical molecules

each can be considered as an elastic ball.

very small.

Origin of pressure — Impulse of collision between the molecules and the wall of container.

Temperature and average kinetic energy:

$$\frac{3}{2} k T = (\varepsilon_K)_{ave}.$$

OR.

$$\frac{3}{2} k T = \left(\frac{1}{2} m v^2\right)_{ave}. \qquad (v^2)_{ave} = \frac{3kT}{m}.$$

∴ RMS speed of gas molecule

$$v_{rms} = \sqrt{(v^2)_{ave}} = \sqrt{\frac{3kT}{m}}.$$

RMS — Root mean squared.