Thermal expansion, RMS speed, Heat, Thermodynamics

Read 11.1–11.4, 11.5–11.9
12.1–12.8

Chap 11: efficiency $e = \dfrac{\text{what you get out}}{\text{what you pay (in)}}$

Temp + KE

1 molecule: $KE_{avg} = \frac{1}{2}mv_{avg}^2 = \frac{3}{2}k_B T$

N molecules: $E_{th} = N \cdot \frac{3}{2}k_B T$

Thermodynamics

T = temp

Q = heat added or subtracted

W = work - mechanical energy

E_{th} = thermal energy of gas due to motions of molecules

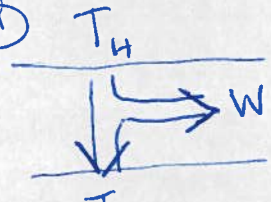
1st Law $\Delta E_{th} = W + Q$

- ΔE_{th}: + temp goes up
- W: + work done on gas
- Q: + heat added to gas

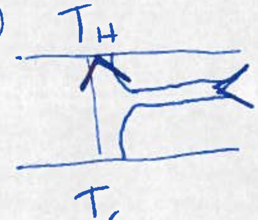
Heat engine: transfer heat hot → cold to do work (A)

or

use work to transfer heat cold → hot (B)

(A)


engine does work

(B)


refrigerator takes work, moves heat from T_C

Efficiency of heat engine/refrigerator: use **Kelvin**.

heat engine: $e = \frac{W}{Q_H} \Rightarrow 1 - \frac{T_c}{T_H}$ always < 1

refrigerator: $e = \frac{Q_c}{W} \Rightarrow \frac{T_c}{T_H - T_c}$

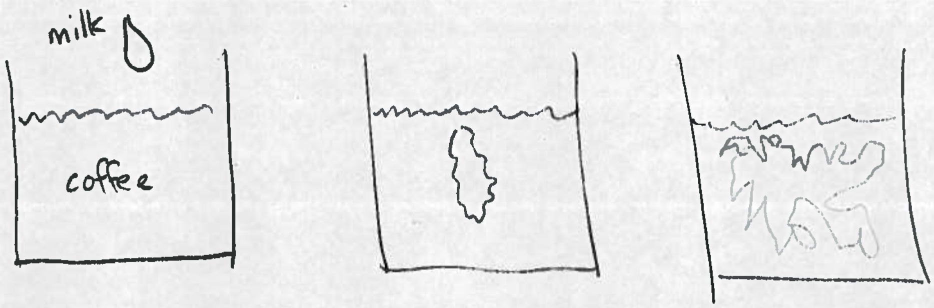
heat pump: $e = \frac{Q_H}{W} = \frac{T_H}{T_H - T_c}$

(refrigerator and heat pump: can be > 1)

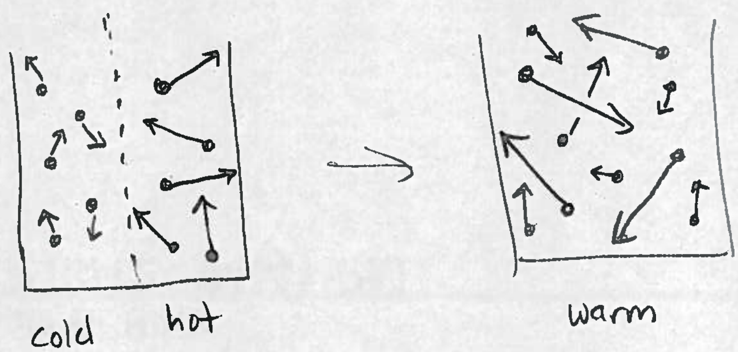
2nd Law of Thermodynamics:

The entropy (messiness, disorder) of an isolated system never decreases.

mix coffee + milk



mix cold air and hot air



Chapter 12

mole: $1 \text{ mole} = 6.02 \times 10^{23}$ molecules

If the molecular weight of a molecule is 32 (such as O_2), then 1 mole will weigh 32 grams.

molecular speed

In a gas, molecules move with a range of speeds. But "average" speed

$$v_{avg} = v_{rms}$$

is given by

$$K_{avg} = \frac{1}{2} m v_{rms}^2$$

or

$$K_{avg} = \frac{3}{2} k_B T \qquad T \text{ in Kelvin}$$

so

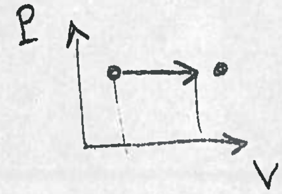
$$v_{rms}^2 = \frac{3 k_B T}{m}$$

ideal gas law

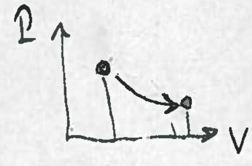
$$PV = N k_B T = nRT$$

work done by ideal gas in engine

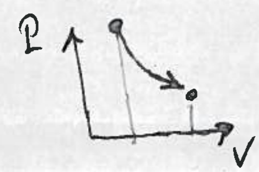
isobaric $P = \text{const}$ $\quad W = p(V_f - V_i)$



isothermal $T = \text{const}$ $\quad W = nRT \ln\left(\frac{V_f}{V_i}\right)$



adiabatic $Q_{in} = 0$, $Q_{out} = 0$ $\quad W = -\frac{3}{2} nR(T_f - T_i)$



Thermal expansion – if you add heat, an object expands

linear : $\Delta L = \alpha L_i \Delta T$

volume : $\Delta V = \beta V_i \Delta T$

Specific heat : if you add heat, how much does temperature chang

$$Q = M c \Delta T$$

- Q ← heat added (J)
- M ← mass (kg)
- c ← specific heat (J/kg·°C)
- ΔT ← change in temp °C, °K

<u>but</u>, if a material changes phase : boil, melt, freeze
then extra heat needed to make the change

$Q = M L_f$ if object freezes or melts

$ = M L_v$ if object evaporates/condenses

for ideal gases

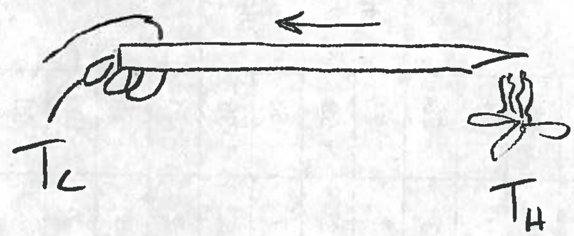
$Q = \frac{3}{2} nR \Delta T$ if volume constant

$ = \frac{5}{2} nR \Delta T$ if pressure constant

Heat Transfer - moving heat from one place to another

$$\frac{Q}{\Delta t} = \frac{\text{heat moved}}{\text{time taken}} = \frac{\text{Joules}}{\text{sec}} = \text{Watts}$$ <u>Power</u>

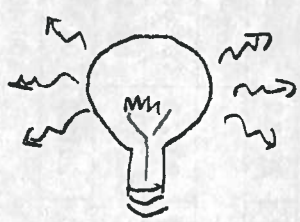
Convection: heat flowing through solid object



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

k = thermal conductivity
A = cross section area
L = length
$\Delta T = T_H - T_C$

Radiation: heat transferred by electromagnetic waves



$$\frac{Q}{\Delta t} = e\sigma A T^4$$

e = emissivity of object (close to 1.0)
$\sigma = 5.67 \times 10^{-8} \left(\frac{\text{Watts}}{m^2 \cdot K^4}\right)$
A = area of object (m^2)
T = temp of object (Kelv