What is internal energy

**Equipartition theorem (not proved):**

- Each term in the total energy that is proportional to a velocity $^2$ or a position $^2$ gets $\frac{1}{2} k_B T$ of thermal energy, on average.

Caution: 1) System must be in thermal equilibrium

- $k_B T >>$ energy difference between quantum levels

$T =$ absolute temperature

This is really the definition of $T$.

Example: Free particle $E = \frac{1}{2} m v_x^2 + \frac{1}{2} m v_y^2 + \frac{1}{2} m v_z^2$

- Each of these three terms in $E$ gets $\frac{1}{2} k_B T$

Example: Mass & spring $E = \frac{1}{2} m v^2 + \frac{1}{2} k x^2$

- Each of these two terms in $E$ gets $\frac{1}{2} k_B T$

Internal energy is the energy described by the equipartition theorem, i.e. the kinetic & potential energy of the atoms. Because the atomic motions are too small for us to see, we call this collective energy "internal energy".

Conservation of energy

- Can add heat directly to the system

\[ W_{ext} + Q_{ext} = \Delta U + \Delta K + \Delta U_{int} \]

Conservation of energy

Work done within the system

If $W_{ext} + Q_{ext} = 0$, then $\Delta U + \Delta K + \Delta U_{int} = 0$.

- We can still have conversions of energy from one form to another within the system. The work done within the system is an agent for such conversions.

Example:

- Mass with initial velocity $v_0$ slides a distance $s$ before coming to rest (because of friction).

\[ W_{friction} = \vec{F}_{friction} \cdot \vec{s} = -F_{friction} \cdot s = \Delta K = -\Delta U_{int} \]

(Note: must think to see how $W_{friction}$ relates to $\Delta K$, $\Delta U$, & $\Delta U_{int}$, including the sign of the relation.)