Justify the laws of thermodynamics from a macroscopic point of view.

1st law :

0th and 2nd law :

Conservation of energy in both macroscope and microscope

Macroscope: an irreversible approach to equilibrium

Microscope: collective tendency of large numbers of degrees of freedom

$$S/N = k_B \ln(g_N)/N \quad , \quad g_N: \text{ degeneracy of states}$$

3rd law :

Macroscope: $\lim_{T \to 0} S = 0$

Microscope: $\lim_{N \to \infty} \ln(g_N)/N = 0$ at $T = 0$

limiting possible number of ground states for a many-body system.

⤷ equivalent to a restriction on degeneracy of ground states of a quantum mechanical system

Limitation of classical statistical mechanics

1. Low temperature and energy (quantum effect)
2. inapplicability to glassy phases
   - freezing of supercooled liquids into configurations with extremely slow dynamics (not truely equilibrium phase but subject to all laws of thermodynamics) → see Problems HW