Microcanonical, canonical, grand canonical ensembles

- $\boxed{S = k \log \Gamma(E)}$
- $\boxed{A = -kT \log Q_N}$
- $\boxed{PV = kT \log \mathcal{Q}_N}$

$$\boxed{\Gamma(E) = \frac{1}{h^{dN} N!} \int_{E < \mathcal{H} < E + \Delta E} d^{dN} \vec{p}\, d^{dN} \vec{q}}$$

$$\boxed{Q_N(T, V) = \frac{1}{h^{dN} N!} \int e^{-\beta \mathcal{H}(\vec{p}, \vec{q})} d^{dN} \vec{p}\, d^{dN} \vec{q}}$$

$$\boxed{\mathcal{Q}(\mu, T, V) = \sum_{N=0}^{\infty} z^N Q_N(T, V)}$$

- Macrovariables: $\boxed{E, N, V}$

  $\boxed{T, N, V}$

  $\boxed{T, \mu, V}$

- Ensemble average: $$\boxed{\langle f \rangle = \frac{1}{\Gamma(E)} \frac{1}{h^{dN} N!} \int_{E < \mathcal{H} < E + \Delta E} f \, d^{dN} \vec{p}\, d^{dN} \vec{q}}$$

$$\boxed{\langle f \rangle = \frac{1}{Q_N(T, V)} \frac{1}{h^{dN} N!} \int_{\text{all space}} f \, e^{-\beta \mathcal{H}} d^{dN} \vec{p}\, d^{dN} \vec{q}}$$

$$\boxed{\langle f \rangle = \frac{1}{\mathcal{Q}(\mu, T, V)} \sum_{N=0}^{\infty} f \, z^N Q_N(T, V)}$$