Thermodynamics: Study of restrictions on possible properties of matter that follow from symmetry properties of fundamental laws of physics.

↳ remain unchanged under some transformation

Noether's Theorem: For every continuous symmetry in physical system, there is conserved quantity

CPT [charge, parity (space), time] symmetry

10^{23} atomic coordinates positions, momenta
||
"normal coordinates"

Macroscopic / Thermodynamic Coordinates: Time independent makes macroscopically observable because

Macroscopic Measurements: slow on atomic time scale, coarse on atomic scale of distance

↳ only coarse spatial averages

↳ accessible normal modes are undestroyed by averaging because homogeneous structure

- Studies of mechanics, electricity focus on two distinct sets of surviving coordinates
- Thermodynamics studies atomic coordinates which do not explicitly appear in macroscopic description of system because of observational coarseness

↳ things that don't survive time / space averaging

- Hidden modes can store energy → Energy transferred to mechanical mode is mech. work

$-P\partial V$

→ " " electrical mode is electr. work

$-E_e \partial P$ (E_e is electric field, P is dipole moment)

↳ Force on charged particles in space

↳ Vector quantity representing separation of +/- charges, measures overall polarity)

→ " " hidden modes is HEAT

$-S\partial T$

Initial focus on "simple systems": macroscopically homogeneous, isotropic, uncharged, neglect surface effects because of size, not acted on by electric, magnetic, grav. fields

Extensive Parameters: Have value in composite system equal to sum of values in subsystem

U Development Timeline:

- 1693, Leibniz → conservation principle for kinetic & potential energy
- 1905, Einstein → relativistic rest-mass energy
- 1930, Fermi → Neutrino, to maintain conservation principle in nuclear reactions

- 1798, Count Rumford → Cannon Boring thermal effects
- Davy, Carnot, Mayer, Joule (1840/50)

took to Rumford

Macroscopic systems have definite & precise energies, subject to a definite conservation principle.

1-10
15

· Only energy differences matter in physical states
· any energy above "fiducial" (benchmark) state matters
· is called internal energy, U | U, V, N are all extensive

> All systems tend to equilibrium states where properties are determined by intrinsic factors and not previously applied external influences <

time independent

⇓ TD seeks to describe these

Postulate 1. Equilibrium states of simple systems solely macroscopically defined by U, V, N_k exist.

• Q: How to determine system in equilibrium (quiescence, static)?
↳ extensive properties defining system, must be t independent / independent of path
↳ ex: glass depends on process characteristics, not in equilibrium

Non-equilibrium state of matter: undergoing continuous irreversible mass & energy changes
↳ detected by failure of TD formalism based on equilibrium

Atomic point of view: macroscopic equilibrium state indicates incessant & rapid transitions among all atomic states consistent w/ bounding conditions → equilibrium = all states
↳ if system stuck in state or too slow, averaging doesn't work → Non-Equilibrium
↳ more common in solids because ~~fluids~~ fluids all random atomic collisions that mitigate restrictions

Few systems in absolute, true equilibrium

Metastable Equilibrium: Relevant processes of spontaneous evolution, ~~are~~ done can be described by small number of parameters, ⇒ all we need for TD

In summary: System is in equilibrium if properties consistently described by thermodynamic theory [circular]
⇓
like mechanics, we don't toss theory if it fails → just add more terms!