Phase Space

:- Phase space is the set of all possible positions(r) and momenta (p) of a physical system. It is fundamental concept in classical statistical mechanics used to discribed the microscopic state of a system. It is ~~omitted~~ multidimentional mathematical space where each axis represents a coordinate of position or momentum for the particles in a system. An instantaneous state of a single particle is represented by a single point in this space, known as phase point or representative point (Coordinates x, y, z, p_x, p_y, p_z - -). 6(six) dimensions (3 for position and, 3 for momentum are called single particle (3 Dimension) and $6N$ dimensions ($3N$ position, $3N$ momentum) are called N particles (3D). phase space is ~~divide~~ divide in two tipes

1) μ-space (Molecular phase space) - A 6 dimensional space used to describe the state of a single particle.

2 - Γ-Space (Gas phase space) — A 6N dimensional space used to describe the state of the entire system of N particles.

✓ Phase Trajectory — As a system evolves in time, it's phase point moves, tracing a path known as a phase trajectory.

✓ Liouville's Theorem — The density of system points in phase space remains constant in time as the system evolves (incompressible flow) which is foundational for understanding equilibrium.

✓ phase volume ($d\tau$) — A small region in phase space is defined by its volume element

$$d\tau = dx, dy, dz, dp_x, dp_y, dp_z$$

Examples of phase space —

~~1) 1D (S.H.O)~~

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$H = \frac{p^2}{2m} + \frac{1}{2}kq^2$ the phase trajectory is an ellipse in the (q, p) Plane.

2) Free particle in a Box — The phase space volume available depends on the energy and volume of the container, calculated as

$4\sqrt{2}\pi m^{3/2} V E^{3/2}/3$