**4. Systems of More than one Particle**

**4.1 System of Particles**

We can describe the force that acts upon a certain particle, as the positions of all other particles in a system.

Charges and Masse are **intrinsic properties** of a particle.

That comes from the fact that gravitational forces and electrical forces are proportional to the masses and charges of particles respectively.

Apart from the intrinsic properties, forces also depend on the location of particles.

These locations can be denoted in several ways.

Firstly, the one we will use, for now, is the xi, yi , zi

Which are the coordinates of the ith particle on the cartesian.

Secondly, the other one we will use,

Which denotes the set of all positions, of all particles in a system, or in other words

**It represents all the position vectors of all particles in a system.**

So as we said earlier,

Once we know the position of every particle, we can use Newtons equations of motion to find the trajectory and expected path of a particle.

(ex. Particle 1)

Since acceleration is the time derivative of velocity, or the second time derivative of position, we can rewrite this as:

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Or in component Form:

**4.2 The State Space of a System of Particles**

The **state-space** of a system of particles, is the **collection of all possible** states of the system.

The **State** of a System of Particles, consists of the collection of all the positions and velocities of all particles in the system at the given time t.

That shows us that the state space is a 6D space. What 6D space means, although it is really counter-intuitive to think about fitting six perpendicular to each other axes, is that the configuration space (state space) is made up by the 3 position components and 3 velocity components. In general, that means that at every **given time t, each particle’s state is given by those 6 components.**

**4.3 Momentum and Phase Space**

**Momentum of a particle is defined as the product of its velocity and mass.**

**Momentum Space** is like the Configuration space, with the only differences being that it is 3D instead of 6D, and instead of **position and velocity,** a state of the system at a given point is given by the 3 **components of momentum**, summing up for the 3D space.

We mentioned the Configuration Space of a system, but in Classical Mechanics, we don’t use it that much. What we use is the phase space. Since velocity and momentum are so closely linked, we can use momentum over velocity to define each state. So in simpler words, **phase space = configuration space + momentum space**.

And

**4.4 Action, Reaction and the conservation of momentum**

Conservation of momentum is basically Newtons 3rd law of motion.

**For every action there’s an equal, with respect to magnitude, and opposite with respect to direction, reaction.**

Suppose we have a closed system where particles interact in pairs. The overall force acting upon a particle at a certain time t, is the sum of all forces exerted upon at that time t.

If we denote the force o++++n particle i **due to particle j** by the symbol then the **total** force acting on particle I is

nj being the number of all particle in the system minus the particle i

It follows that

So we could denote the rate of change of momentum as the sum of any particle I as the sum of all the forces due to all the other particles in the system. If you take a moment and think about it, it something very intuitive.

So if we take it further it follows that

Is the rate of change of the total momentum.

Now according to Newtons 3rd Law, that

Which means that so if we substitute this to

We get that

Or

And that is the Conservation of momentum‼!