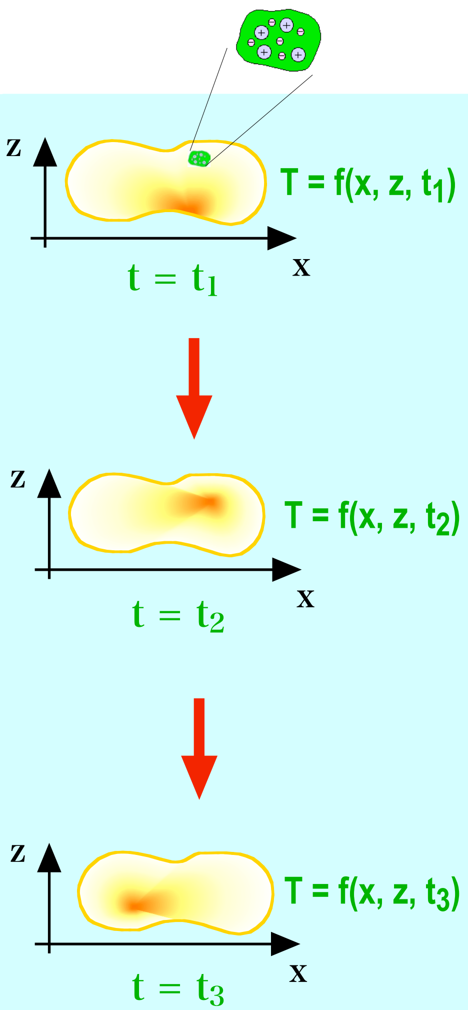
Fluid approach... Focus on the density, flow velocity, pressure, temperature of a **fluid element** in space-time (these are statistically averaged quantities derived from position & velocity distributions of particles)

=> **Fluid dynamics equations**



In the fluid approach, we consider the **physical state** of a **fluid element** represented by **statistically averaged quantities** such as **density**, **flow velocity**, **pressure**, and **temperature**. For example, **temperature** changes with **position** and **time**, so it is expressed as a **function of position** and **time**:

$$T = f\left(x, z, t\right)$$

Temperature field

continuously distributed in space-time

Particles do not fill up the space, whereas fluid elements do that.

The equation for temperature field is a **differential equation** where **position** and **time** are **independent variables** (partial differential equation, PDE).

$$\frac{\partial T}{\partial t} = \alpha \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2} \right)$$

Kinetic approach

(in the case of mechanics)

$$
\begin{cases}
m\dfrac{dv_x}{dt} = F_x\big(x(t), y(t), z(t), v_x(t), v_y(t), v_z(t), t\big) \\
m\dfrac{dv_y}{dt} = F_y\big(x(t), y(t), z(t), v_x(t), v_y(t), v_z(t), t\big) \\
m\dfrac{dv_z}{dt} = F_z\big(x(t), y(t), z(t), v_x(t), v_y(t), v_z(t), t\big)
\end{cases}
,\quad
\begin{cases}
\dfrac{dx}{dt} = v_x(t) \\
\dfrac{dy}{dt} = v_y(t) \\
\dfrac{dz}{dt} = v_z(t)
\end{cases}
$$

× N (number of particles)

... 6N ordinary differential equations
+ Maxwell's equations

Fluid approach

(in the case of magnetohydrodynamics)

$$\frac{\partial \rho}{\partial t} + \nabla \bullet (\rho \boldsymbol{v}) = 0$$ ... for ρ

$$\rho\left(\frac{\partial \boldsymbol{v}}{\partial t} + \boldsymbol{v} \bullet \nabla \boldsymbol{v}\right) = -\nabla p + \frac{1}{\mu_0}(\nabla \times \boldsymbol{B}) \times \boldsymbol{B} + \boldsymbol{F}$$ ... for v_x, v_y, v_z

$$\frac{\partial}{\partial t}\left(\frac{p}{\gamma - 1}\right) + \nabla \bullet \left(\frac{p}{\gamma - 1}\boldsymbol{v}\right) = -p\nabla \bullet \boldsymbol{v} + \nabla \bullet (\kappa_c \nabla T) + \frac{j^2}{\sigma}$$ ... for P

$$\frac{\partial \boldsymbol{B}}{\partial t} = \nabla \times \left(\boldsymbol{v} \times \boldsymbol{B} - \eta_{diff} \nabla \times \boldsymbol{B}\right)$$ ... for B_x, B_y, B_z

... 8 partial differential equations
(+ equation of state)

Because of local charge neutrality $\rho_c \sim 0$, Coulombic electric field does not exist globally (but electric field associated with time-varying magnetic field globally exists).

Since electric current globally exists while keeping the local charge neutrality, magnetic field globally exists.