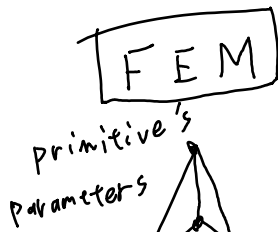


If the object has fixed point, the correspond coordinates are fixed.



$$\begin{aligned} \epsilon &= B u && \text{strain-displacement} \\ \sigma &= D \epsilon && \text{stress-strain} \end{aligned}$$

volume  $\downarrow$

$$\text{strain energy: } \frac{V}{2} \sigma^T \epsilon = \frac{V}{2} u^T B^T D B u$$

external force:  $u^T f$

total energy

$$\frac{V}{2} u^T B^T D B u - u^T f$$

minimum parameter

$$K u = f$$

what we solve  $u$

$$V B^T D B u = f$$

$Ax = b$   
This type equation is usually solved by an iterative method e.g.) CG method

**Newton phys.**

mass  $\rightarrow$

$$M \ddot{x} = f$$

$$\begin{aligned} v &= v_0 + \int_{t_0}^t f(t)/m \, dt \\ (\dot{x} &= v) \end{aligned}$$

We want to know next step's configuration  $x_{t+1}$  and  $v_{t+1}$  when we have  $x_t, v_t$  and  $f_t$ .

One could write

$$\begin{cases} v_{t+1} = v_t + \Delta v \\ x_{t+1} = x_t + \frac{v_{t+1}}{\Delta t} \end{cases}$$

time step  $\rightarrow$

And then, we can use explicit/implicit integration method to solve them on the computer

explicit integration  
e.g. forward Euler method, Runge-Kutta Integration and Verlet Integration

$$\begin{pmatrix} \Delta x \\ \Delta v \end{pmatrix} = h \begin{pmatrix} M^{-1} f_t \end{pmatrix}$$

we just assign past values.

implicit integration

$$(m) \Delta v = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$$

something something

