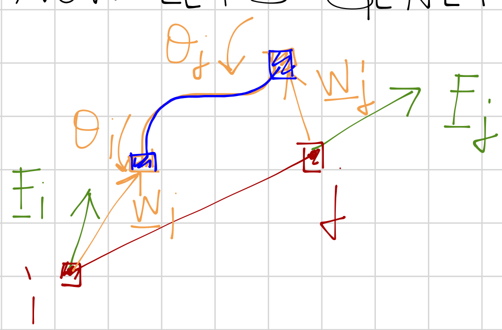
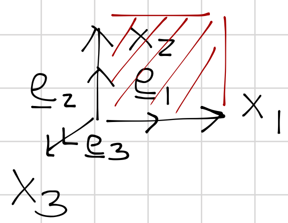
NOW LET'S GENERALIZE IT TO MULTIPLE DIMENSIONS



WE FIRST CONSTRUCT A DIRECTOR VECTOR

$$\underline{n} = \frac{\underline{q}_j - \underline{q}_i}{\ell} \quad , \quad \ell = |\underline{q}_j - \underline{q}_i|$$

THEN WE CONSTRUCT A NORMAL VECTOR



$$\underline{n} = \alpha \underline{e}_1 + \beta \underline{e}_2$$

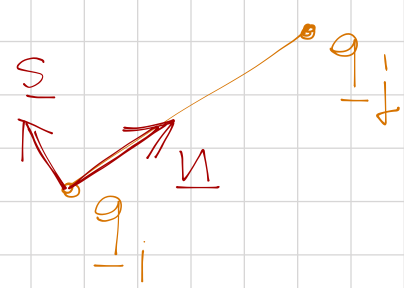
$$\underline{n} \times \underline{e}_3$$

OR ROTATE

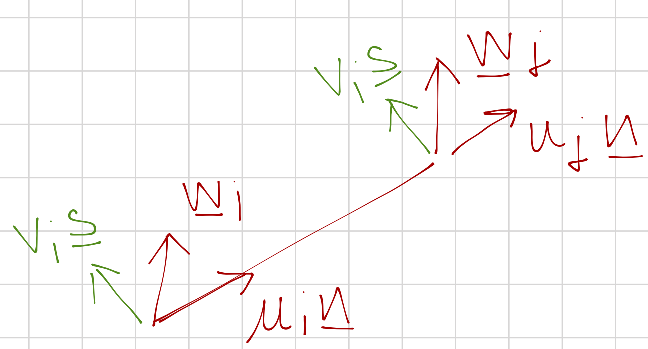
$$\underline{\underline{R}} = -1\, \underline{e}_1 \otimes \underline{e}_2 + \underline{e}_2 \otimes \underline{e}_1$$

S.T.

$$\underline{s} = \underline{\underline{R}}\, \underline{n}$$



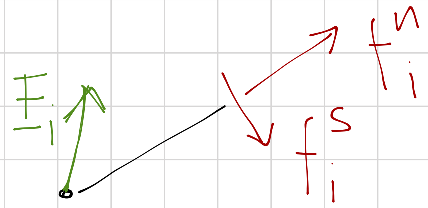
NOW, YOU RECALL THAT FOR TRUSSES



$$u\, \underline{n} = (\underline{n} \otimes \underline{n})\, \underline{w}$$

SIMILARLY NOW WE CAN WRITE

$$v\, \underline{s} = (\underline{s} \otimes \underline{s})\, \underline{w}$$



$$\underline{F}_i + f_i^n \underline{n} - f_i^s \underline{s} = 0$$

$$\Rightarrow \underline{F}_i = -f_i^n \underline{n} + f_i^s \underline{s} = \frac{AE}{\ell}(u_i - u_j)\underline{n}$$

$$+ \left[\frac{12EI}{\ell^3}(v_i - v_j) + \frac{6EI}{\ell^2}(\theta_i + \theta_j) \right] \underline{s}$$

$$= \left[\frac{AE}{\ell} \underline{n} \otimes \underline{n} + \frac{12EI}{\ell^3} \underline{s} \otimes \underline{s} \right] (\underline{w}_i - \underline{w}_j)$$

$$+ \frac{6EI}{\ell^2} \underline{s} \quad (\theta_i + \theta_j)$$

$$\underline{F}_i = \left[\underline{\underline{K}}_{fw} \quad \underline{K}_{f\theta} \quad -\underline{\underline{K}}_{fw} \quad \underline{K}_{f\theta} \right] \begin{Bmatrix} \underline{w}_i \\ \theta_i \\ \underline{w}_j \\ \theta_j \end{Bmatrix}$$