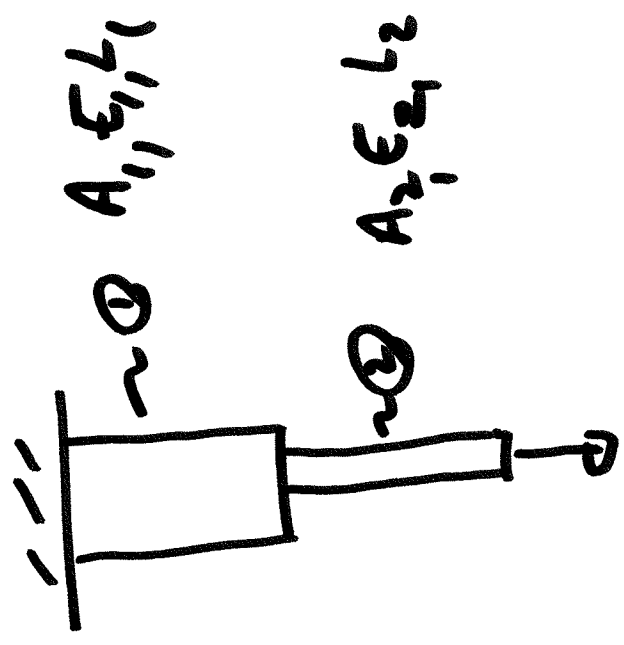
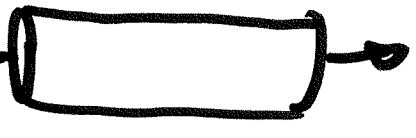


Solution Space & 1ST / 2ND order elements



BAR ELEMENT
 (analogous to spring element)



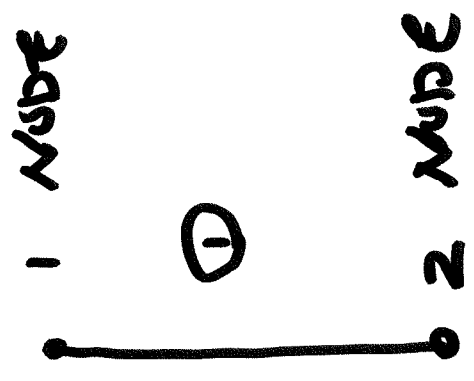
$$\Delta L = \frac{FL}{AE}$$

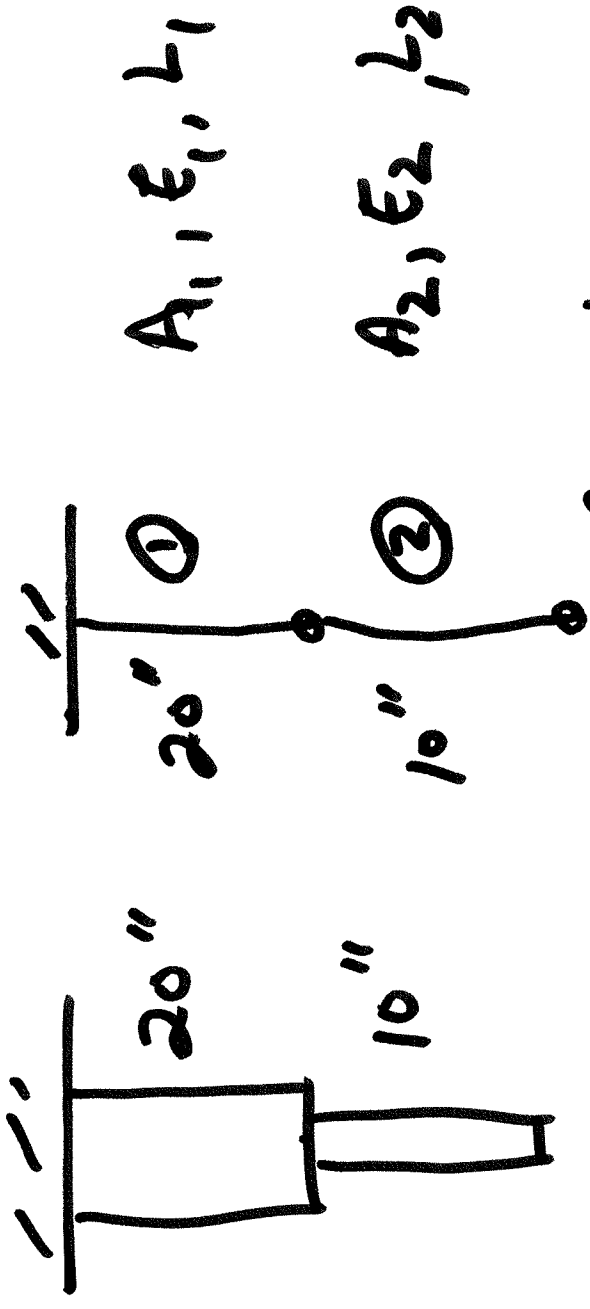
change in length of bar with constant F, A, E over L

OR

$$F = \frac{AE}{L} \Delta L$$

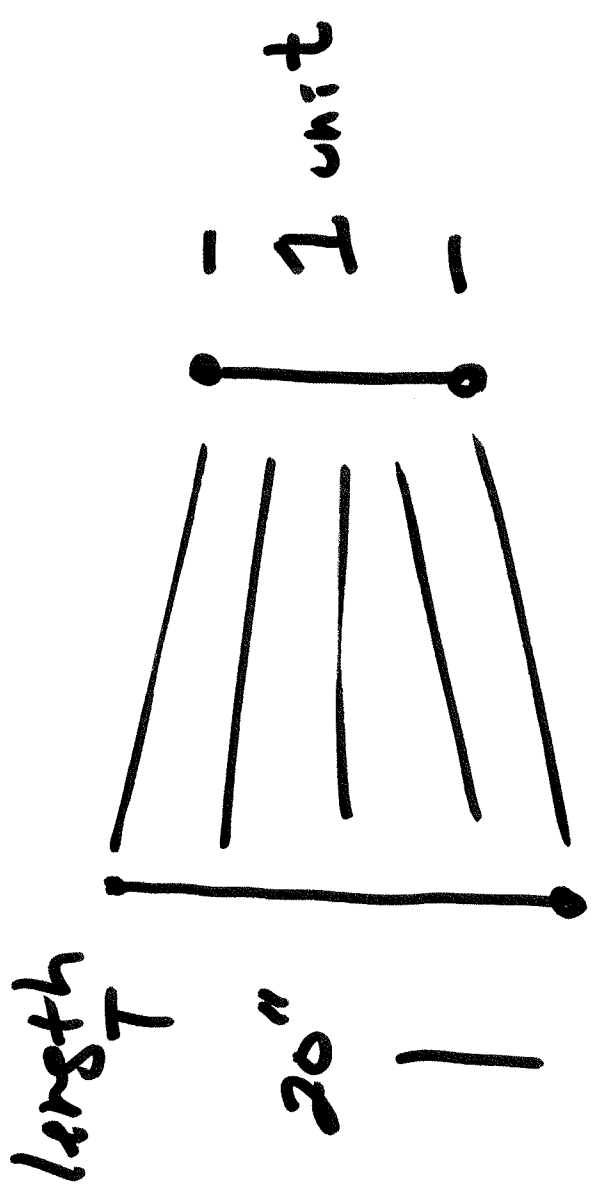
$$F = k \gamma$$



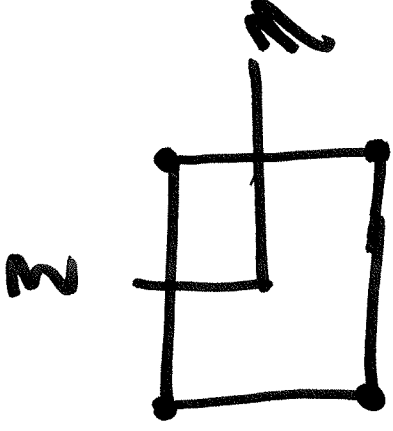
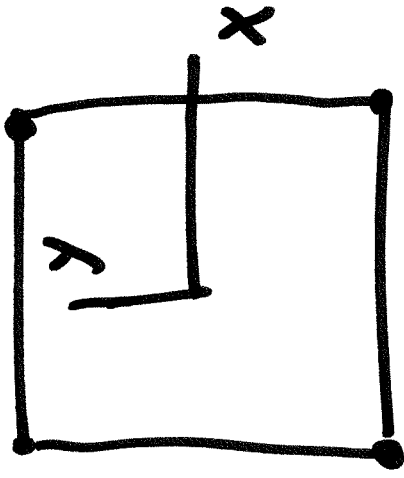


Physical mesh

The element is formulated to have unit



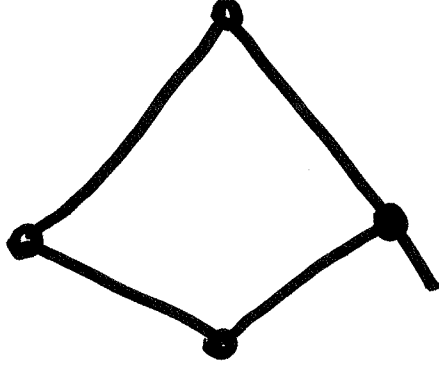
2-D elements



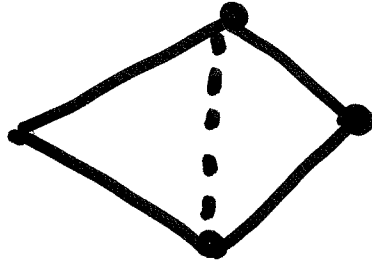
unit element

The physical element is mapped to the unit element.

For mesh quality, make elements as near to square as possible.

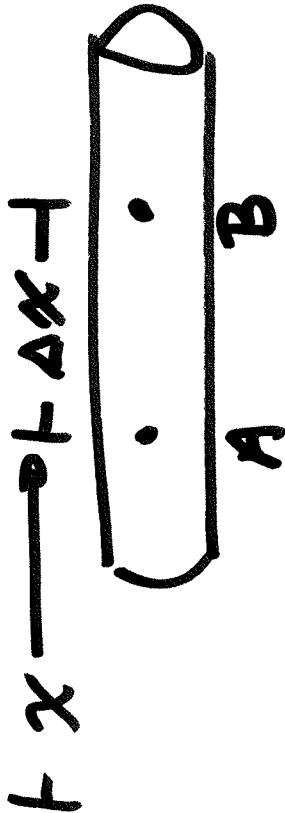


If you cannot avoid sharp angles,
then use triangles.



Use the tools menu in HyperMesh to
check elements quality (aspect ratio,
angles, etc.)

Strain at a point



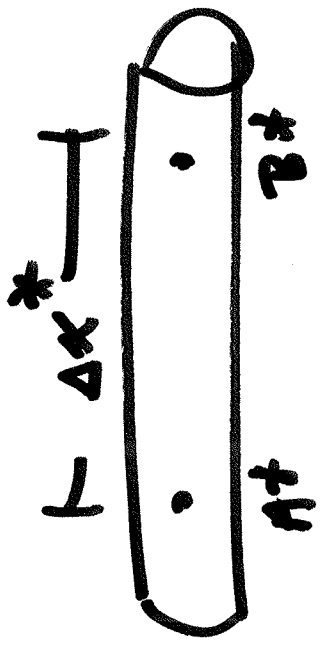
stretch
bar

$$\epsilon_{AB} = \frac{\Delta x' - \Delta x}{\Delta x}$$

$\Delta x' - \Delta x$ relative change in displacement between A & B

$$= \underbrace{u(x + \Delta x)}_{\text{displacement at pos. B}} - \underbrace{u(x)}_{\text{displacement at pos. A}}$$

$$\epsilon_{AB} = \frac{u(x + \Delta x) - u(x)}{\Delta x}$$



$$\epsilon_{PT} = \lim_{\Delta x \rightarrow 0} \frac{u(x + \Delta x) - u(x)}{\Delta x}$$

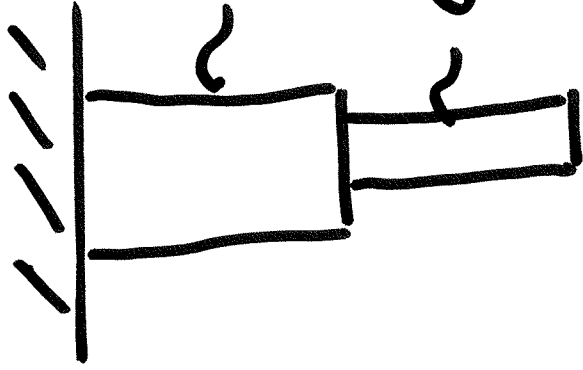
$$\epsilon = \frac{du}{dx}$$

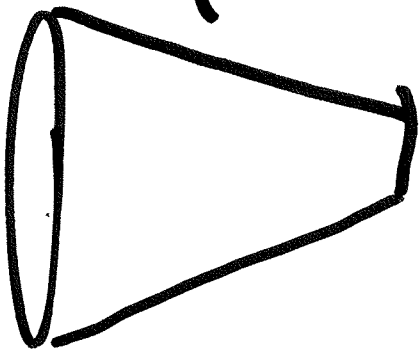
$$dx = \epsilon dx$$

$$u = \int_0^L \epsilon dx + \text{const}$$

deformation

Rigid movement





~ not constant strain

in this case, we need to use a function for our element that captures the non-uniform strain distribution.

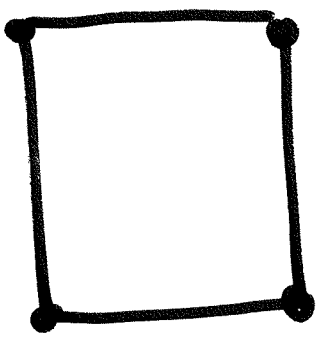


$$u = C_1 x^2 + C_2 x + C_3$$

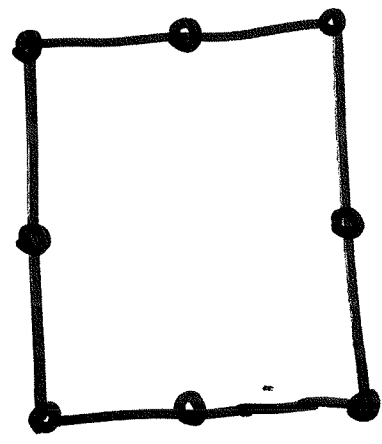
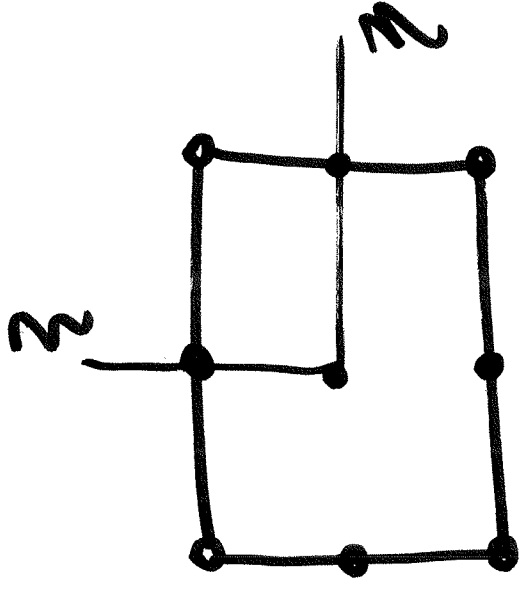
Higher order u requires more nodes

2nd order element

2-D elements

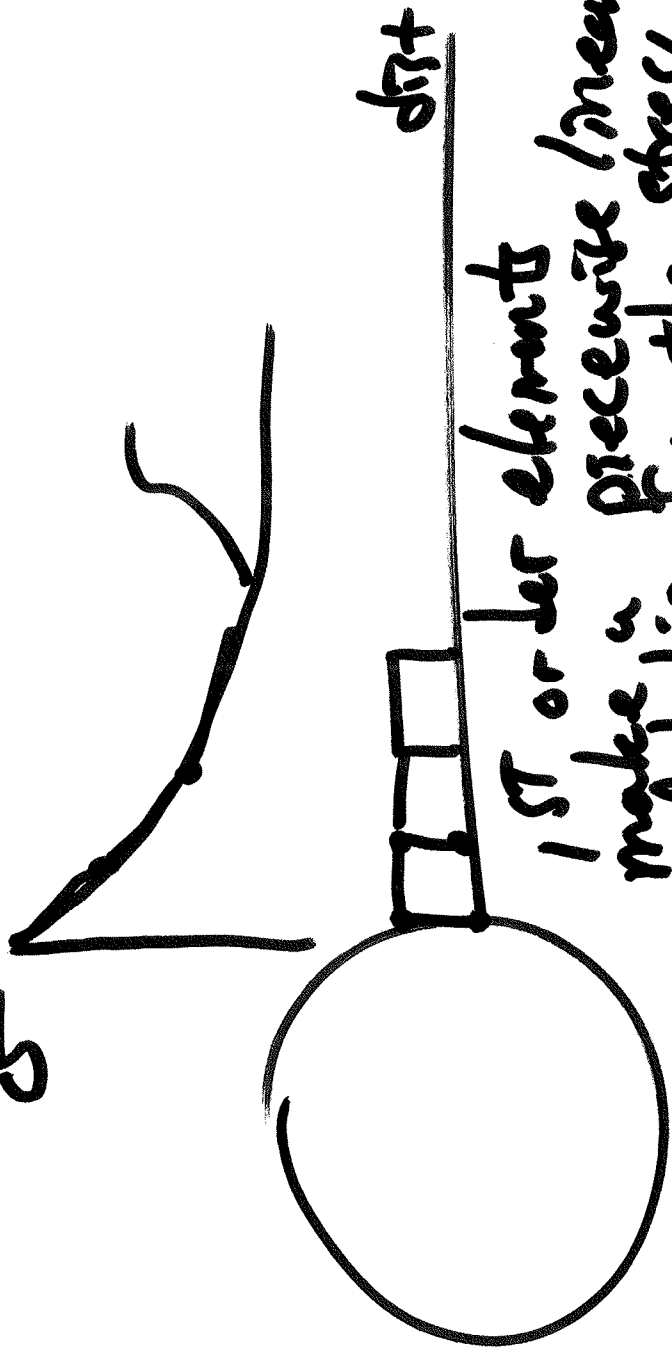


1st order
quad
4 nodes

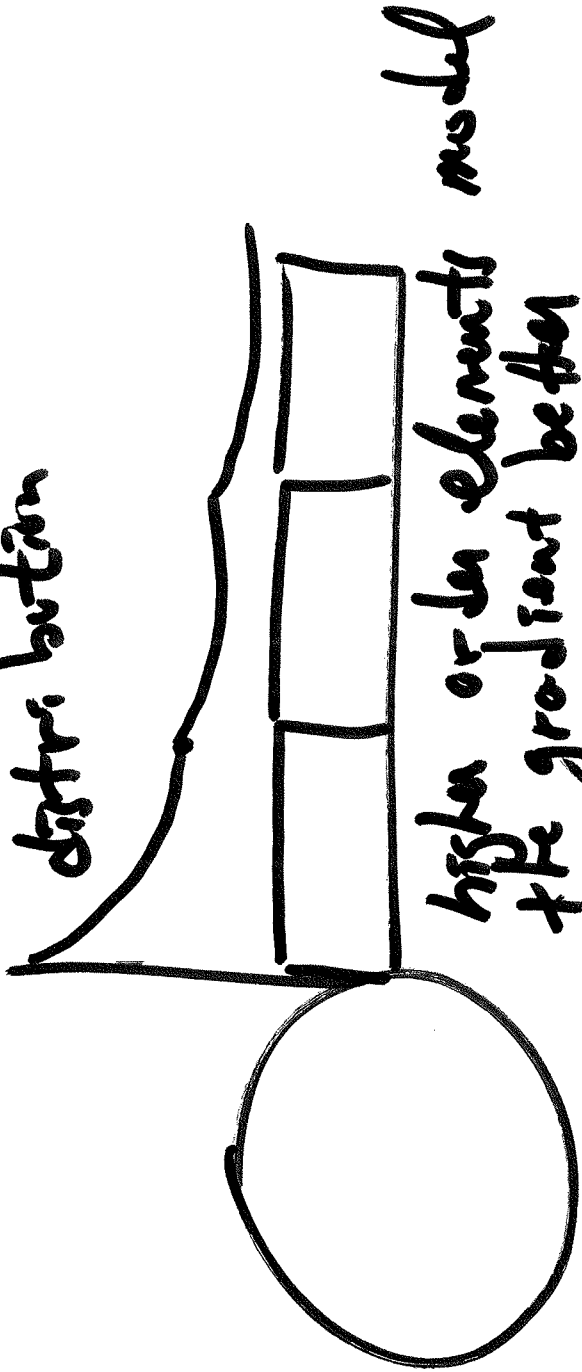


8 noded quadrilateral
2nd order

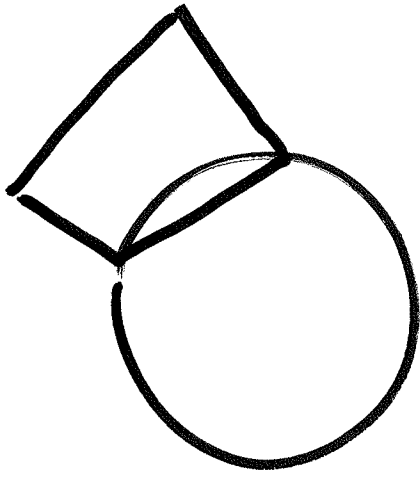
5



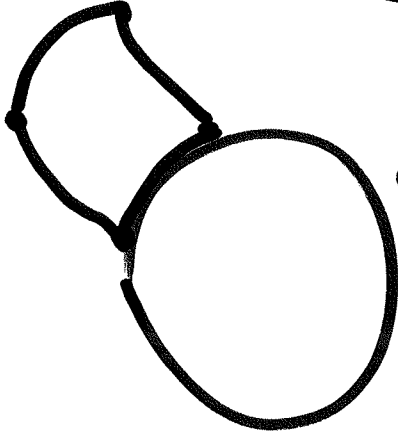
1st order elements
make a piecewise linear
calculation for the stress
distrib. better



higher order elements model
the gradient better

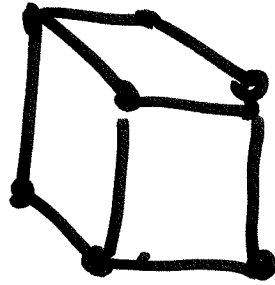


1ST ORDER



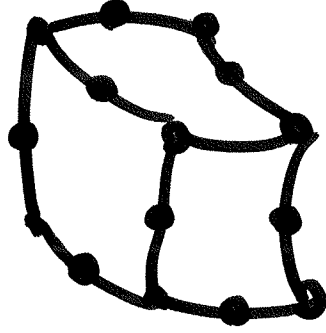
2ND ORDER

Also 3-D elements



8 NODES

1ST ORDER



20 NODES

2ND ORDER