2016/09/27

Tuesday, September 27, 2016

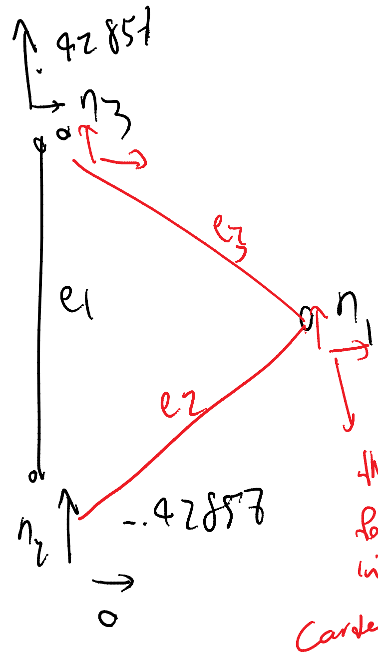
10:07 AM

Ansys:

How to list element end point forces

Postprocess -> element solution -> Structural forces

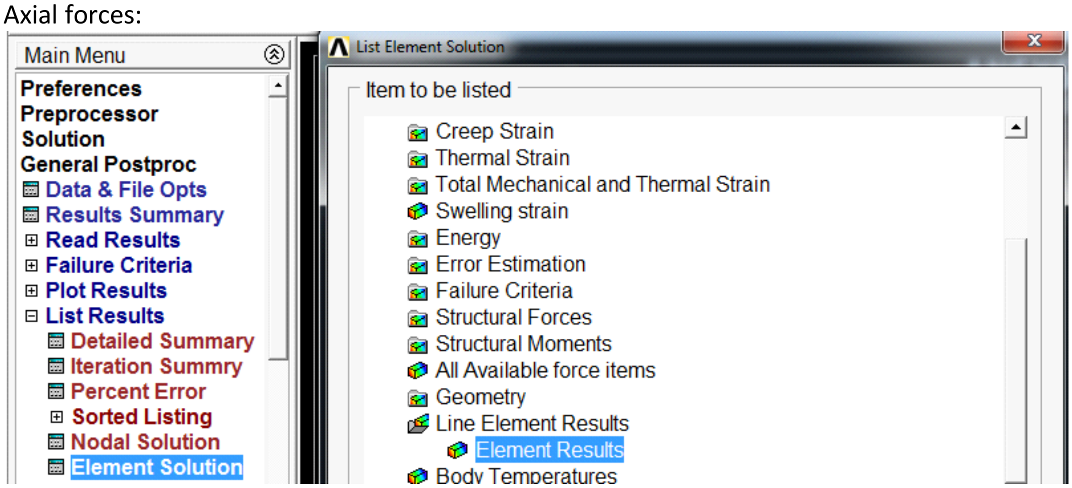
ELEM=	1 FX	FY	FZ
2	0.0000	0.42857	0.0000
3	0.0000	-0.42857	0.0000



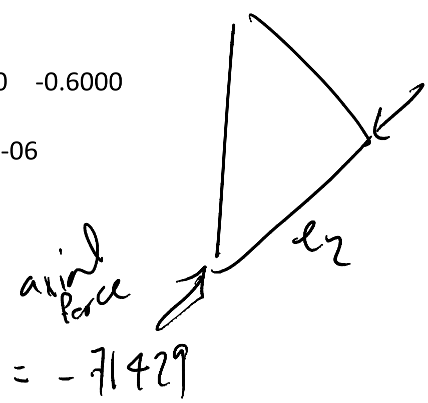
these forces in Cartesian system are very useful

Get axial forces

Axial forces:

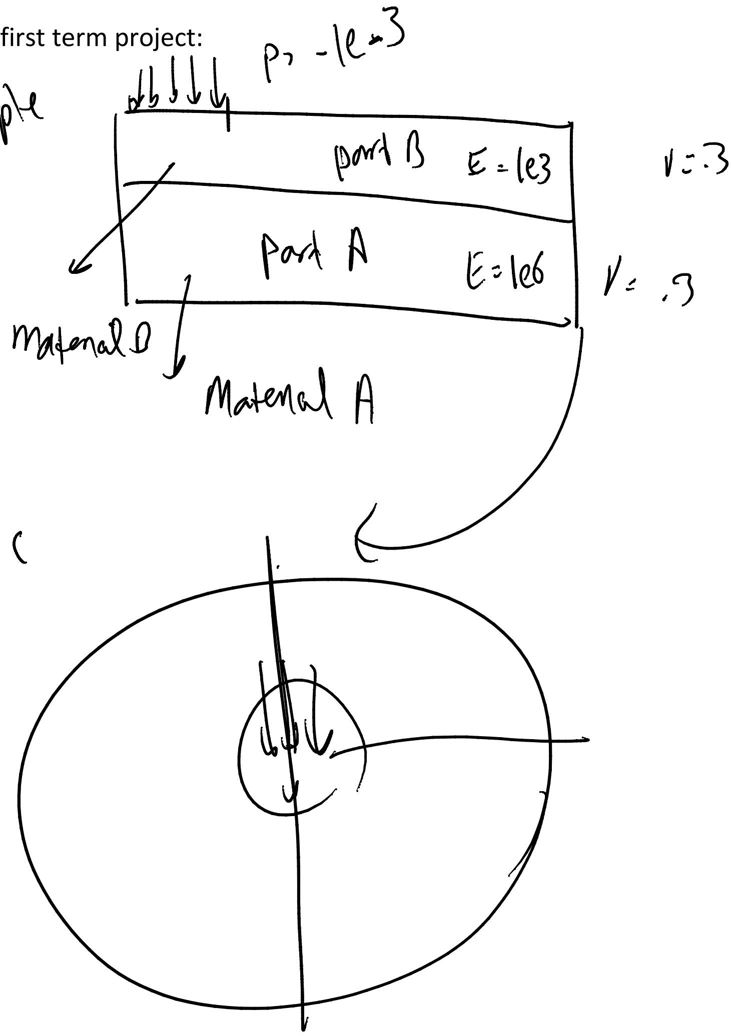


EL= 2 NODES= 2 1 MAT= 1 XC,YC,ZC= 0.8000 -0.6000
0.000 AREA= 1.0000 LINK180
FORCE=-0.71429 STRESS=-0.71429 EPEL=-0.71429E-06
TEMP= 0.00 0.00 EPTH= 0.0000



Second example related to the first term project:

Axisymmetric example

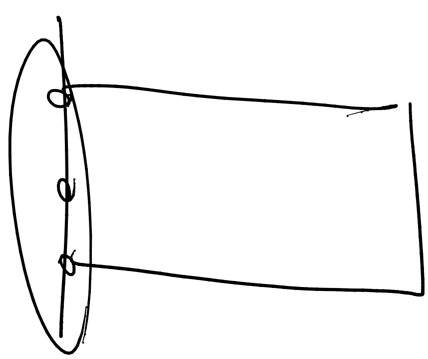


axis

of

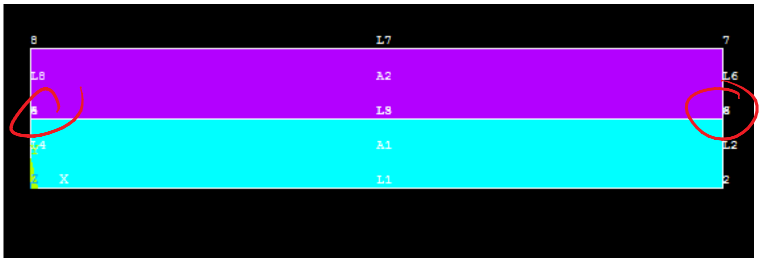
rotation

for axisymmetry problem make sure left edge is on y-axis.



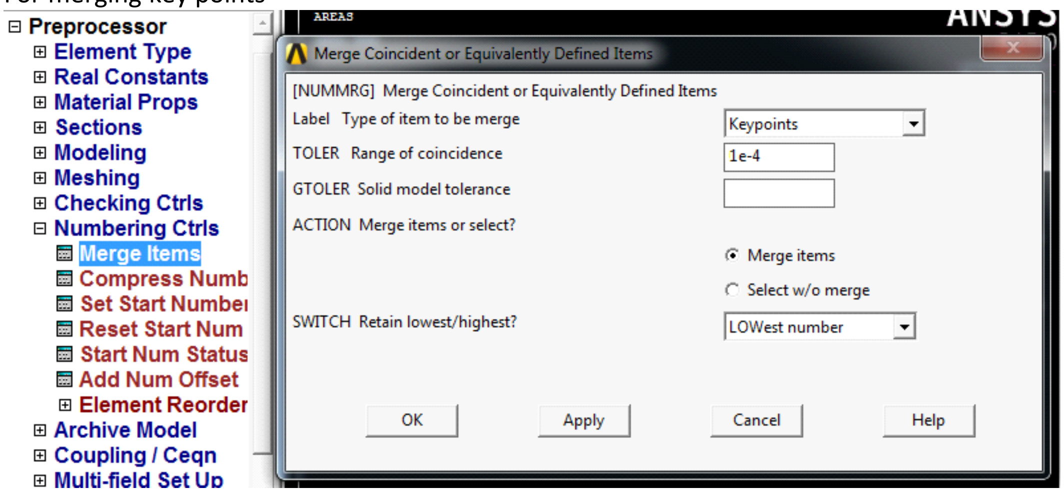
x = 0

How to merge duplicate keypoints?

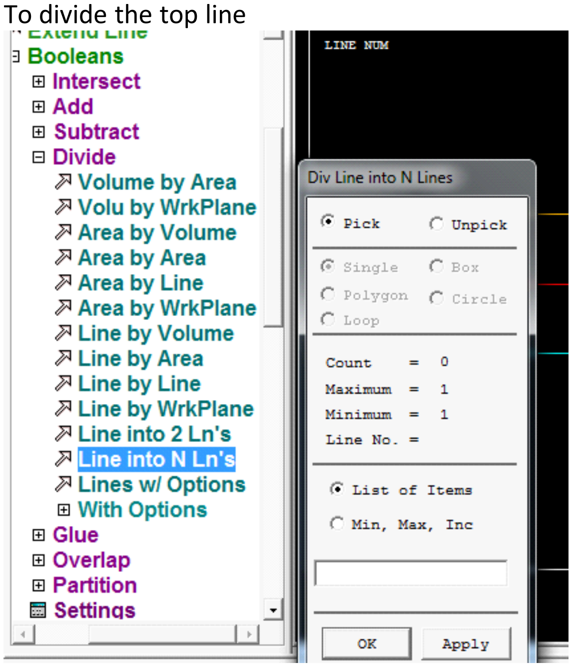


Want to merge them

For merging key points

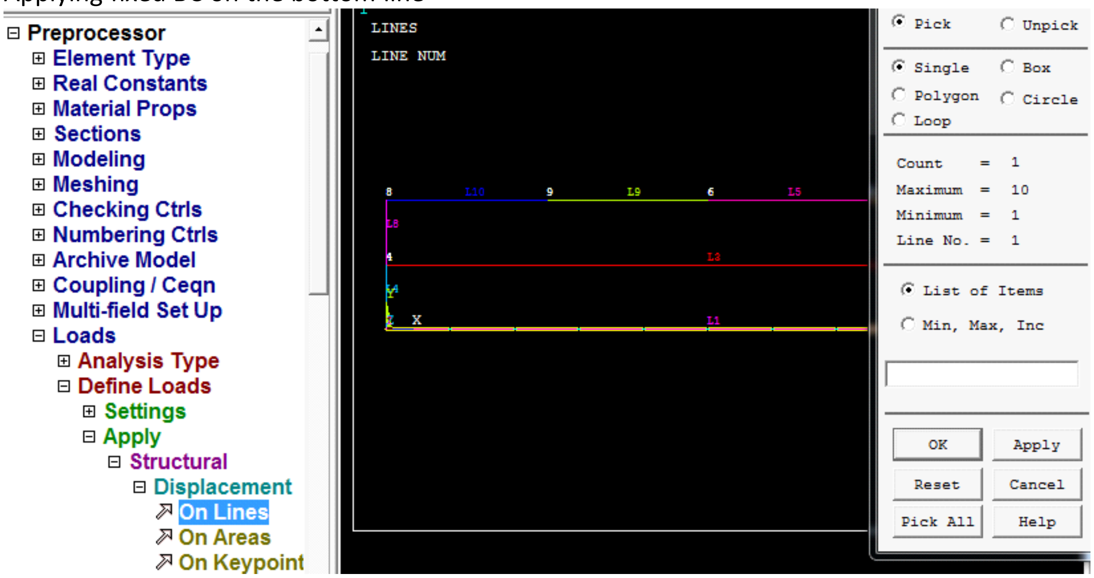


To divide the top line

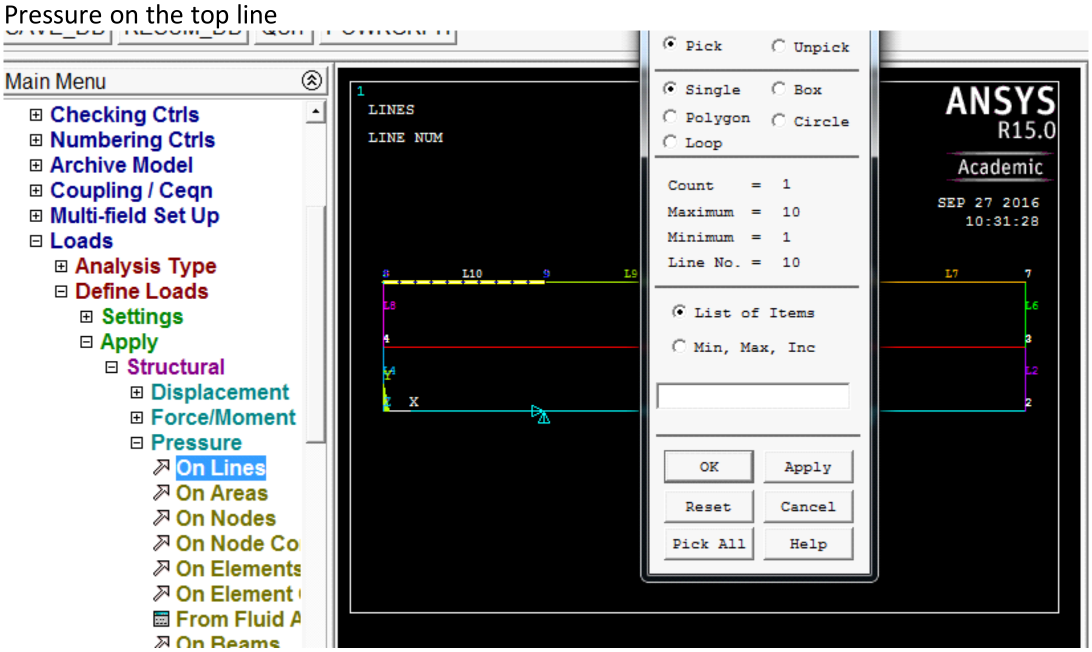


Always apply loads (BCs) to geometry rather than directly applying them to elements and nodes of finite element mesh.

Applying fixed BC on the bottom line

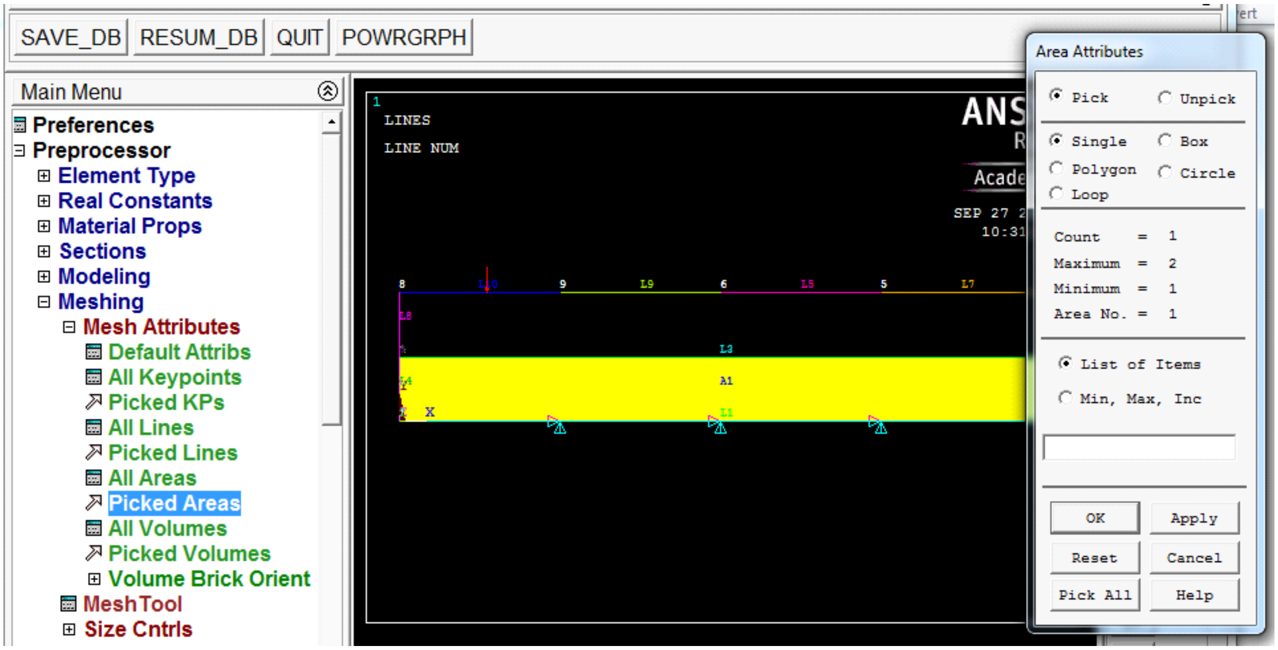


Pressure on the top line

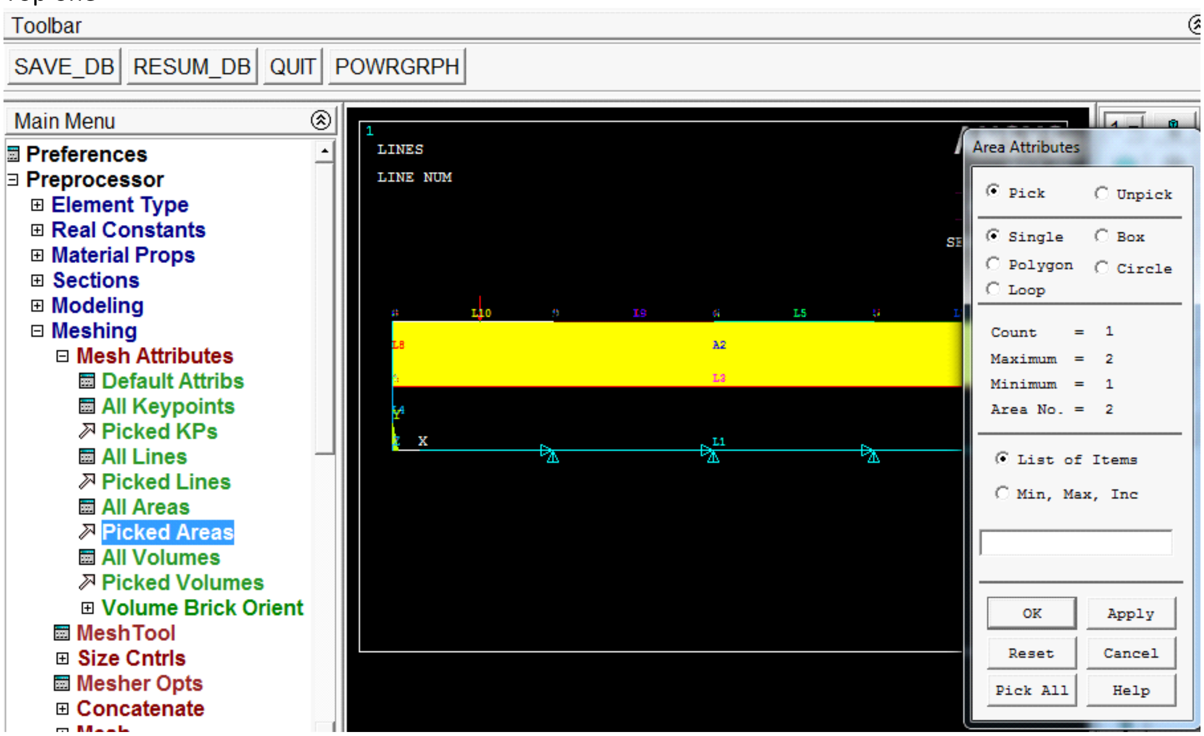


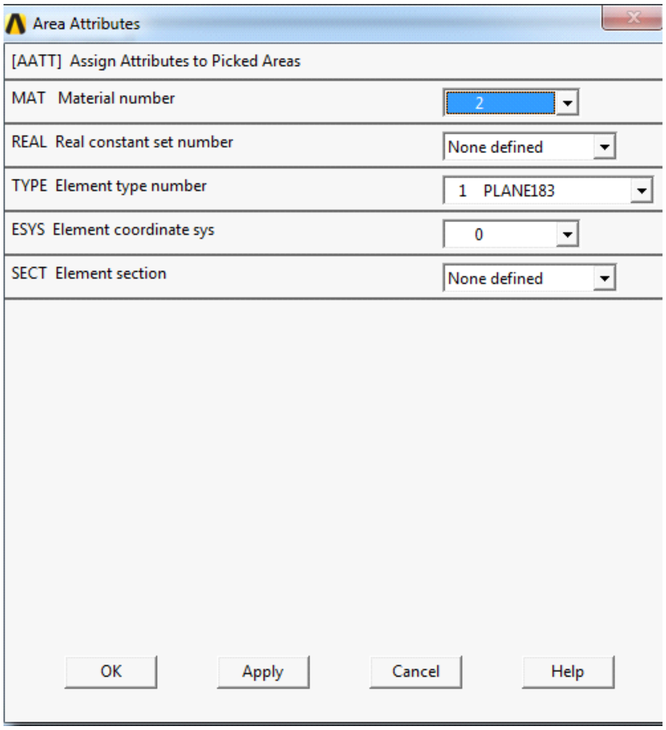
Assigning material numbers to surfaces A and B (bottom and top surfaces)

Choose the bottom area

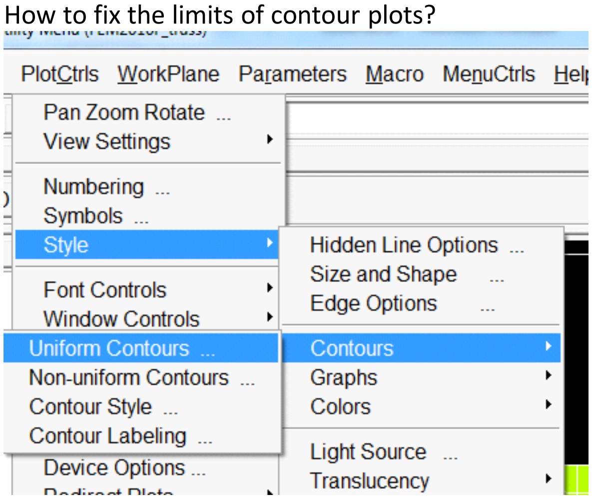

SAVE_DB
RESUM_DB
QUIT
POWRGRPH
Main Menu
Preferences
Preprocessor
Element Type
Real Constants
Material Props
Sections
Modeling
Meshing
Mesh Attributes
Default Attribs
All Keypoints
Picked KPs
All Lines
Picked Lines
All Areas
Picked Areas
All Volumes
Picked Volumes
Volume Brick Orient
MeshTool
Size Cntrls
LINES
LINE NUM
Area Attributes
Pick
Unpick
Single
Box
Polygon
Circle
Loop
Count = 1
Maximum = 2
Minimum = 1
Area No. = 1
List of Items
Min, Max, Inc
OK
Apply
Reset
Cancel
Pick All
Help

Top one


Toolbar
SAVE_DB
RESUM_DB
QUIT
POWRGRPH
Main Menu
Preferences
Preprocessor
Element Type
Real Constants
Material Props
Sections
Modeling
Meshing
Mesh Attributes
Default Attribs
All Keypoints
Picked KPs
All Lines
Picked Lines
All Areas
Picked Areas
All Volumes
Picked Volumes
Volume Brick Orient
MeshTool
Size Cntrls
Mesher Opts
Concatenate
LINES
LINE NUM
Area Attributes
Pick
Unpick
Single
Box
Polygon
Circle
Loop
Count = 1
Maximum = 2
Minimum = 1
Area No. = 2
List of Items
Min, Max, Inc
OK
Apply
Reset
Cancel
Pick All
Help



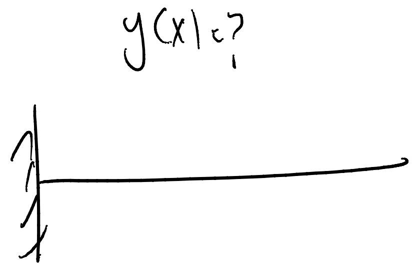
How to fix the limits of contour plots?



Discretization

1. General idea of discretization and how a system Ka = F
    a. K stiffness matrix
    b. a unknown vector
    c. F force vector
2. Do this derivation for various forms of Weighted residual statement, energy method, least square
3. Actual numerical examples

Discretization means turning a problem with infinite unknowns to one with finite number of unknown



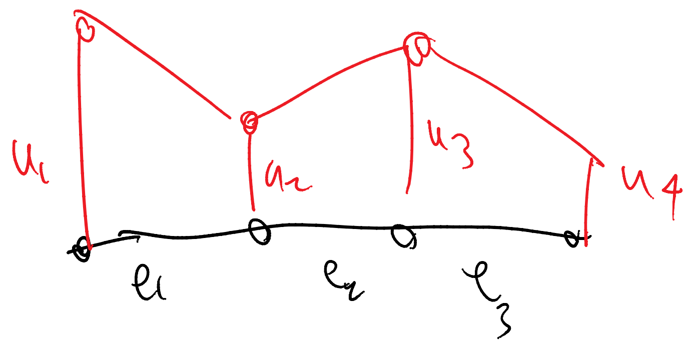
Approximate solution:

$$y = a_1 + a_2 x + a_3 x^2 + a_4 x^3$$

4 unknowns a_1 to a_4

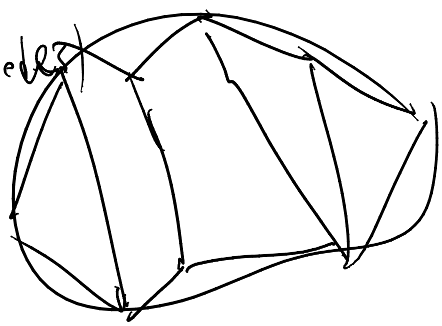
but they don't have geometric interpretation

How about FEM



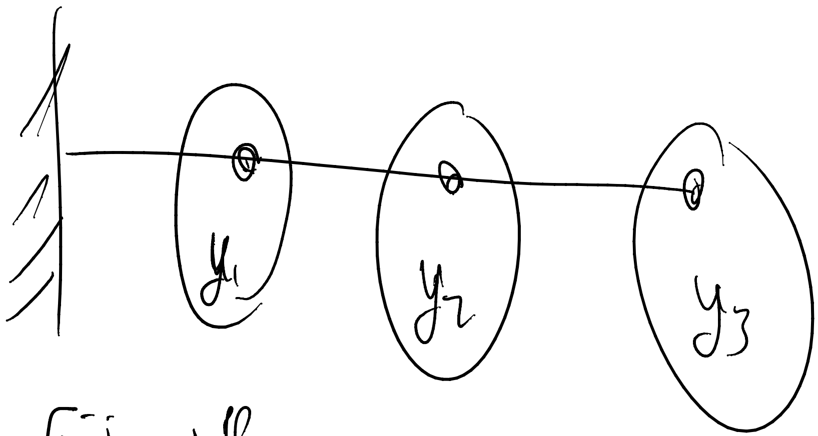
u_1, u_2, u_3, u_4 are the 4 unknowns. They have geometric interpretation (displacement at element nodes)

2D



How do we discretize the solution?

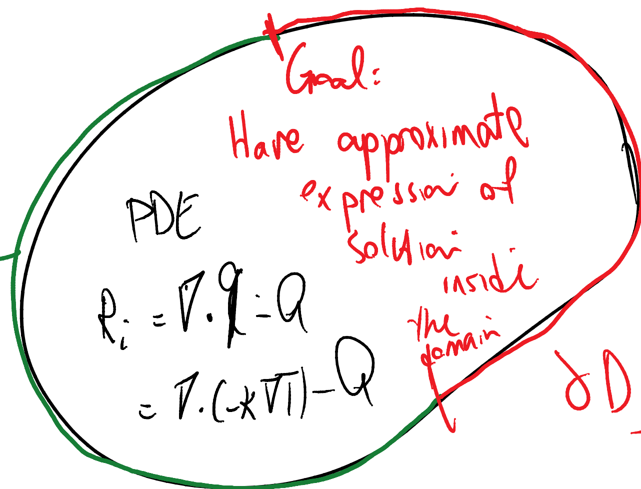
- Finite difference approach / finite volume
  Unknowns are primary fields (e.g. displacements) at grid point locations



Finite difference

The unknowns are y's at certain locations

2. Interpolating the solution with functions



$$R_i = \nabla\cdot q - Q = \nabla\cdot(-k\nabla T) - Q$$

∂D_u essential BC

$$T(x) = \bar{T}(x) \quad \text{for } x \in \partial D_u$$

∂D_f

$$q(x)\cdot n = \bar{q}$$

$$(-k\nabla T)\cdot n = \bar{q}$$

$$R_u = \bar{T}(x) - T(x)$$

$$R_f = \bar{q} - q\cdot n = \bar{q} + (k\nabla T)\cdot n$$

\# unknown

$$T(x) = \sum_{i=1}^{n} \phi_i(\vec{x})\, a_i$$

$$T(x) = \sum_{i=1} \phi_i(\vec{x})\, a_i$$

(x_1, x_2) in 2D

$\phi_i(x)$: trial (test) function

known WE CHOOSE these functions

a_i : unknowns that we want to solve

n: number of unknowns

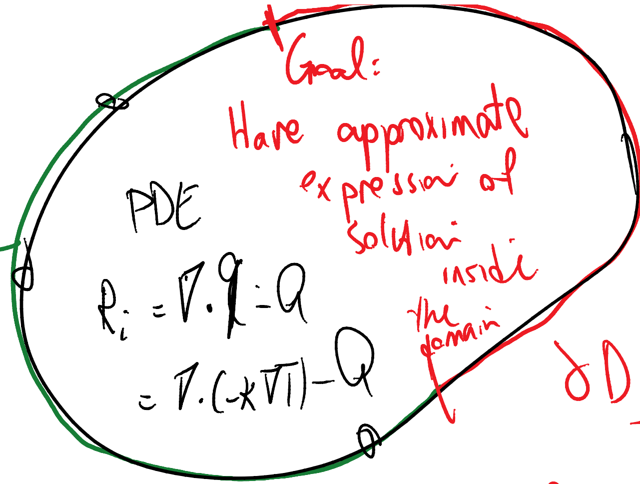
Example

$$y(x) = 1\, a_1 + x\, a_2 + x^2 a_3 + x^3 a_4$$

$\phi_1(x) = 1$ $\quad \phi_2(x) = x$ $\quad \phi_3(x) = x^2$ $\quad \phi_4(x) = x^3$

ϕ_1 to ϕ_4 $\quad \sin x \quad \sin 2x \quad \sin 3x \quad \sin 4x$

Do we need to stipulate any conditions on these test functions?



∂D_u
essential BC

$T(x) = \bar{T}(x)$
for $x \in \partial D_u$

$x_o \in \partial D_u$

∂D_f

$q(x) \cdot n = \bar{q}$

$(-k \nabla T) \cdot n = \bar{q}$

$R_u = \bar{T}(x) - T(x)$

$R_f = \bar{q} - q \cdot n =$

$\bar{q} + (k \nabla T) \cdot n$

We almost always use a method that Ru (essential BC residual) is strongly satisfied.

$$T(x) = \bar{T}(x) \qquad \forall x \in \partial D_u$$

want to satisfy this

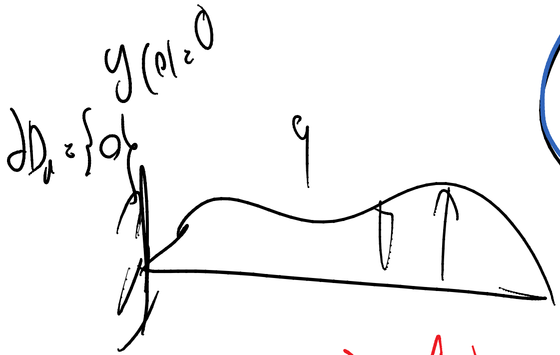
$$T(x) = a_1 \phi_1(x) + a_2 \phi_2(x) + \dots + a_n \phi_n(x)$$

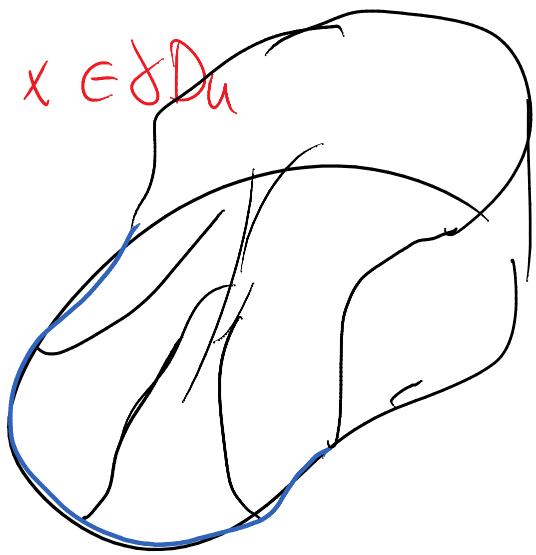
$x_o \in \partial D_u$

$$T(x_o) = a_1 \phi_1(x_o) + a_2 \phi_2(x_o) + \dots + a_n \phi_n(x_o)$$
$$= \bar{T}(x_o)$$

Let's say that all the trial functions satisfy the homogeneous essential BC (similar to weight functions in weak statement)

$\phi_i(x) = 0 \quad \forall\, x \in \partial D_u$





$$y(x) = \cancel{1}\, a_1 + x a_2 + x^2 a_3 + x^3 a_4$$

$\cancel{\phi_1 = 1} \qquad \phi_2 = x \qquad \phi_3 = x^2 \qquad \phi_4 = x^3$

$\phi_i(x) = 0 \quad \forall x \in \partial D_u$

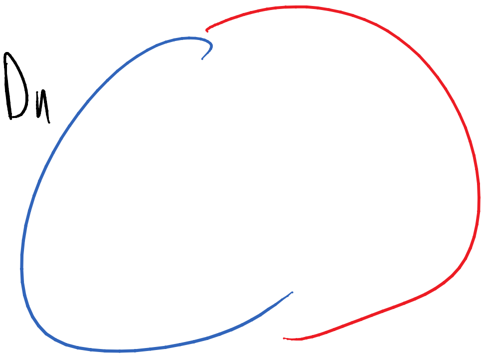
in this case $\phi_i(0) = 0$

$\phi_1(0) = 1 \neq 0$

How do we actually satisfy essential BC (not the homogeneous version of that)?

$$\sum_{i=1}^{n} a_i \phi_i$$

∂D_n



$$T(x) = \overbrace{a_i\, \phi_i(x)}$$

$$\forall x \in \partial D_n \qquad T(x) = a_i\, \overbrace{\phi_i(x)}^{0} = 0$$

not good

Remedy: add a particular function

$$T(x) = \overbrace{a_i\, \phi_i(x)}^{\text{summation from } i=1..n} + \phi_p(x)$$

$$\forall x \in \partial D_n \qquad T(x) = a_i\, \underbrace{\phi_i(x)}_{0} + \phi_p(x) = \bar{T}(x)$$

$$\boxed{\phi_p(x) = \bar{T}(x) \qquad \forall x \in \partial D_n}$$

Particular function ϕ_p satisfies the essential BC strongly

This approach is used by Finite Difference (FD) and Finite Volume(FV) methods.

2. Solution is represented by a finite number of functions:

$$u^h(x) = \phi_p(x) + \sum_{i=1}^{n} a_i \phi_i(x)$$

n unknowns

where u^h is the symbol for discrete solution and $\phi_i(x)$ are trial or test functions. $\phi_p(x)$ is set to satisfy essential boundary conditions and will be discussed later. This approach is used by (discrete) weighted residual method, weak form, least square, and Ritz energy method.

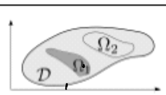
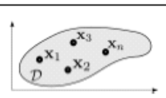
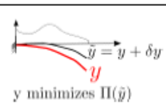
Different approaches that we could get an exact solution ->
How do we discretize these methods

Any expression in the form

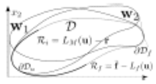
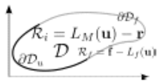
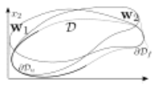
For all

->

For n … (to get n equations rather than infinite equations) so that we get n unknown n equation system

Approach	Equation	Figure	Discretization	Discretization method
Balance Law (20)	$\forall \Omega \subset \mathcal{D} : \int_{\partial\Omega}(\mathrm{f.n})\mathrm{ds} - \int_{\Omega} \mathrm{r\,dv} = 0$		Change $\forall \Omega$ to $\{\Omega_1, \Omega_2, \ldots, \Omega_n\}$	Similar to subdomain method in WRM
Strong Form (23)	$\forall \mathrm{x} \in \mathcal{D} : \nabla.\mathrm{f} - \mathrm{r} = 0$		Change $\forall \mathrm{x}$ to $\{\mathrm{x}_1, \mathrm{x}_2, \ldots, \mathrm{x}_n\}$	Collocation method in WRM. Also FD & FV.
Energy Method (80)	$\forall \tilde{y} \in \mathcal{V} :\ \Pi(y) \leq \Pi(\tilde{y})$		$\forall\{\tilde{a}_1, \ldots, \tilde{a}_n\}$: $\Pi(a_1, \ldots, a_n) \leq \Pi(\tilde{a}_1, \ldots, \tilde{a}_n) \Rightarrow \frac{\partial \Pi}{\partial a_1} = \cdots = \frac{\partial \Pi}{\partial a_n} = 0$	Ritz Energy Method. Also yields Weak Form.

$\nabla \Pi = 0$

Approach	Equation	Figure	Discretization	Discretization method
Weighted Residual Method (45)	$\forall \mathrm{w} \in \mathcal{W}$: $\int_{\mathcal{D}} \mathrm{w}.\mathcal{R}_i \, \mathrm{dv} + \int_{\partial\mathcal{D}_f} \mathrm{w}^f.\mathcal{R}_f \, \mathrm{ds} = 0$		Change $\forall \mathrm{w}$ to $\{\mathrm{w}_1, \mathrm{w}_2, \ldots, \mathrm{w}_n\}$	Weighted Residual Method (WRM)
Least Square (51)	$R^2 = \int_{\mathcal{D}} \mathcal{R}_i^2 \, \mathrm{dv} + \int_{\partial\mathcal{D}_f} \mathcal{R}_f^2 \, \mathrm{ds} = 0$		Change $R^2 = 0$ to $\forall\{\tilde{a}_1, \ldots, \tilde{a}_n\}$: $R^2(a_1, \ldots, a_n) \leq R^2(\tilde{a}_1, \ldots, \tilde{a}_n) \Rightarrow \frac{\partial R^2}{\partial a_1} = \cdots = \frac{\partial R^2}{\partial a_n} = 0$	Least Square method, a WRM for linear L_M (& L_f).
Weak Form (74)	$\forall \mathrm{w} \in \mathcal{W}$ $\int_{\mathcal{D}} L_m^w(\mathrm{w}) L_m(\mathbf{u}) \, \mathrm{dv} = \int_{\mathcal{D}} \mathrm{w}.\mathrm{r} \mathrm{dv} + \int_{\partial\mathcal{D}_f} \mathrm{w}.\bar{\mathrm{f}} \mathrm{ds}$		Change $\forall \mathrm{w}$ to $\{\mathrm{w}_1, \mathrm{w}_2, \ldots, \mathrm{w}_n\}$	Weak Formulation

$\nabla R^2 = 0$