Finite-Element Simulation of Rat Femur Bending Test using ANSYS®

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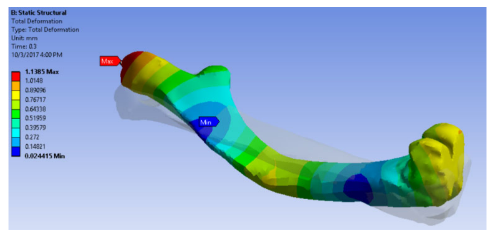
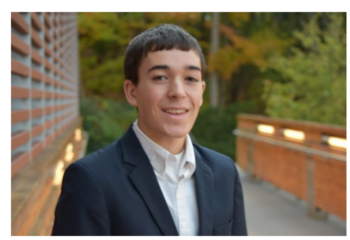


Contact Info

- ANSYS instructor
  - Dr. Rajesh Bhaskaran (rb88)
- Simulation/ANSYS Specialist
  - Keith Works (kaw288)
- ANSYS office hours in Swanson Lab (240 Upson)
  - Dr. Bhaskaran
    - Tue. and Wed. 12:30 - 1:30pm
  - Keith Works(kaw288)
    - Mon. and Tue. 4:30 - 5:30pm
- Wed. and Thu. lab sessions this week will be held in Swanson lab



Keith Works

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Learning Goals

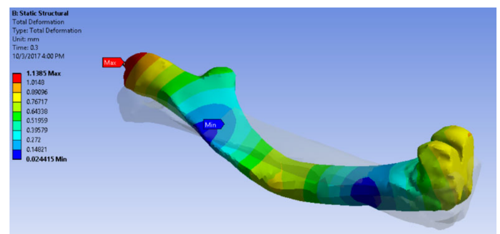
- Learn how to perform biomechanics simulations using a commercial finite-element analysis software package (ANSYS)
- For 3-point bending test of a rat femur, compare
  1. Simulation (finite-element analysis)
  2. Experiment
  3. Hand calculations

ANSYS learning resources:

- Rat femur tutorial
  https://confluence.cornell.edu/x/Cy6JF
- Free online course
  https://www.edx.org/course/hands-introduction-engineering-cornellx-engr2000x-0

Geometry from CT scan

Simulation results



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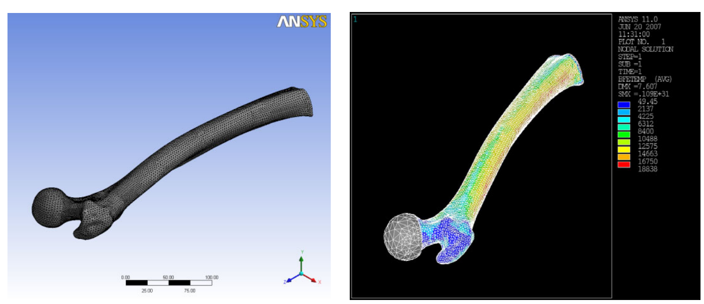
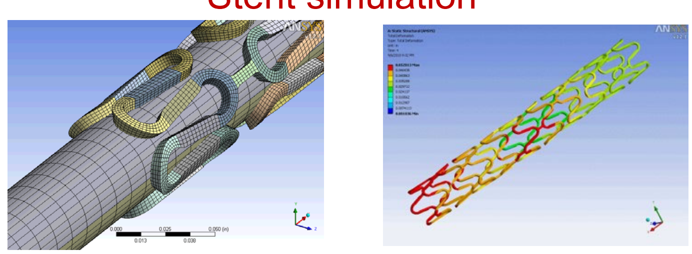
ANSYS Software

- A leading commercial simulation software
- Can solve structural, thermal, fluid flow and electro-magnetic problems
- Founded by Cornell alum Dr. John Swanson in 1970
- Used in over 11 Cornell engineering courses and by many project teams and researchers

Femur simulation



Stent simulation

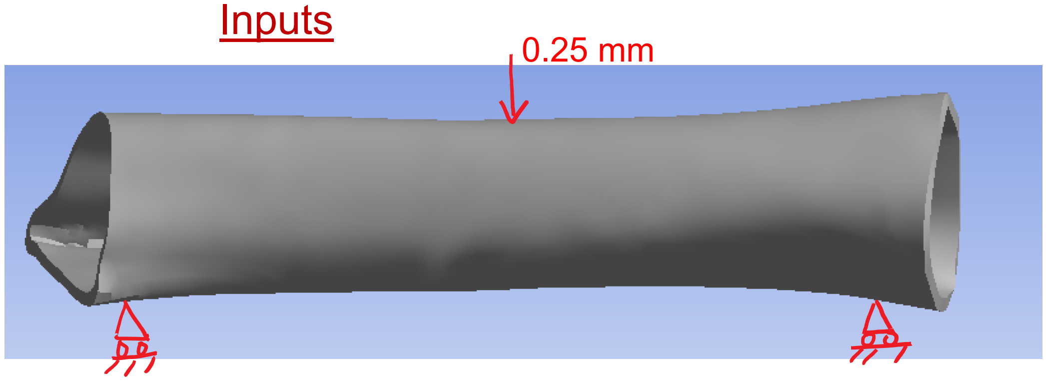


How to Access ANSYS?

- We are using version 2019 R2
- Computer labs
  - Upson 225, Phillips 318, ACCEL lab in Carpenter Hall
  - Swanson lab (240 Upson)
    - Contact Patti Wojcik (pmw27@cornell.edu) if you have problems accessing the lab
- Download free ANSYS Student product for MS Windows machines
  - ansys.com/student
- *Apps on Demand* through Canvas
  - Run in a web browser from anywhere on any device !
  - Important: Save in Google drive after you are done https://youtu.be/4eUWrMThVMo
  - Help page: https://it.cornell.edu/appsondemand/overview-using-apps-demand?utm_source=main

Problem Statement

Inputs



Young's modulus $E = 5\ GPa$ Poisson's ratio $\nu = 0.4$

Outputs

Displacements, strain and stress components, applied force

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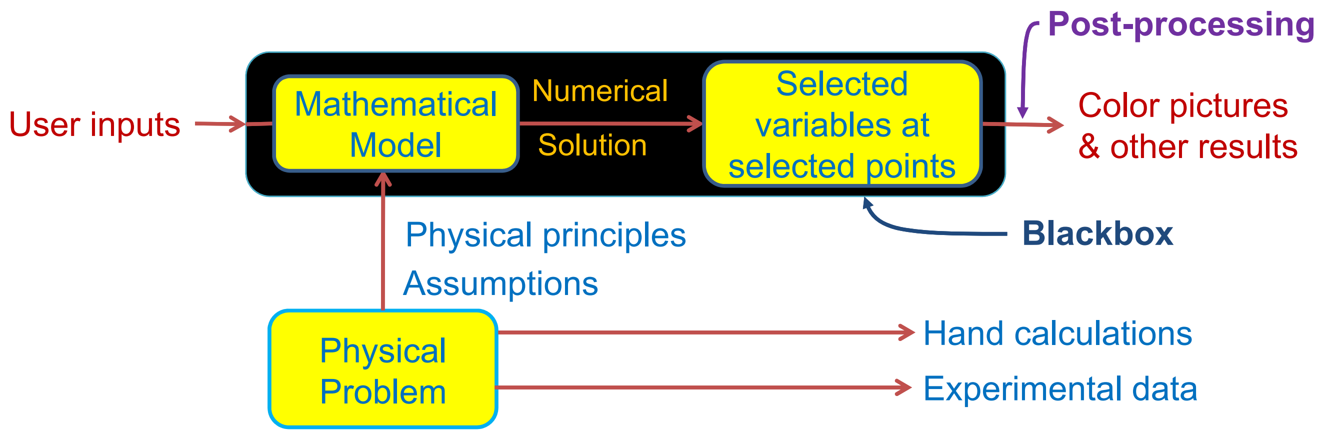
What's Inside the ANSYS Blackbox?



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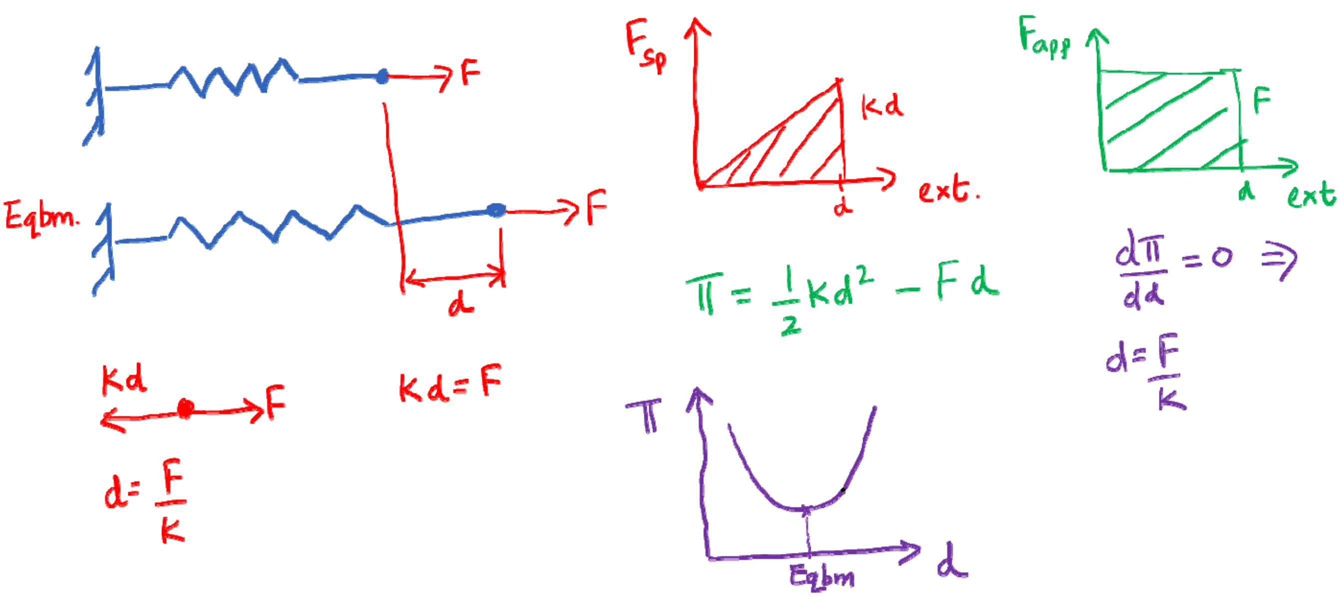
Potential Energy of a Spring Π (Analogy)



Shell Theory Overview

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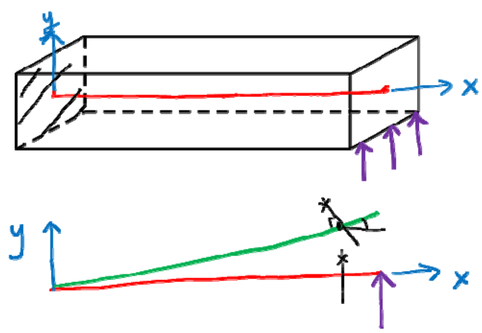
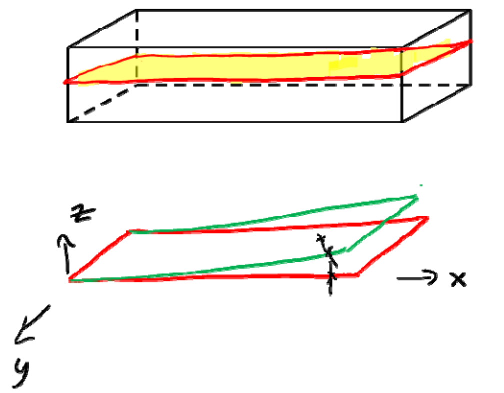
Euler-Bernoulli Beam Theory



Deformed midline → Π

? such that Π is minimized

Plate Theory



Deformed midsurface → Π

? such that Π is minimized

u_z

u_x

u_y

θ_y

θ_x

θ_z

Curved Surfaces

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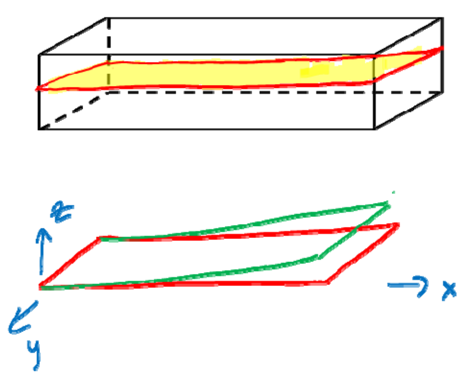
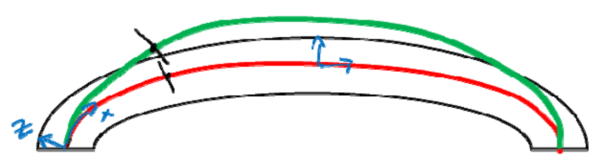
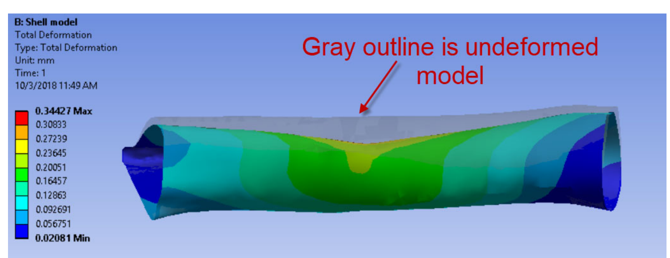
Plate Theory



Shell Theory





See lecture videos at shorturl.at/ejP08

Pre-Analysis: Numerical Solution Strategy

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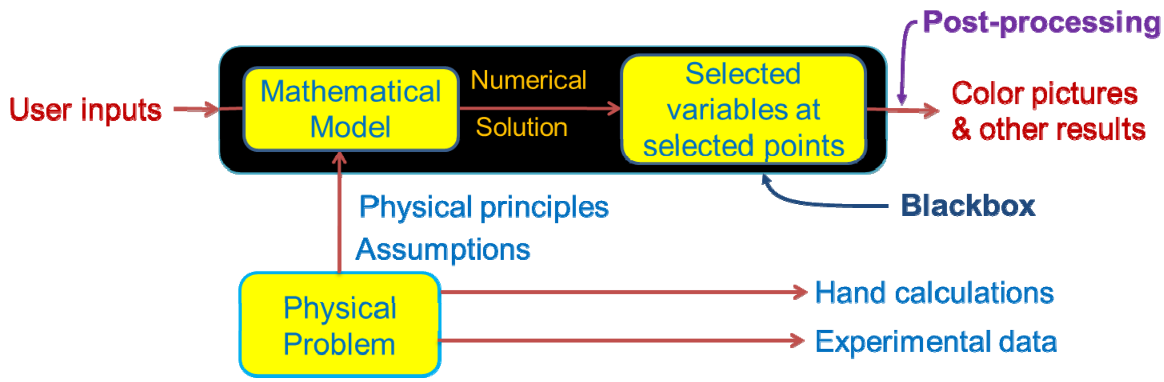

Numerical Solution Strategy

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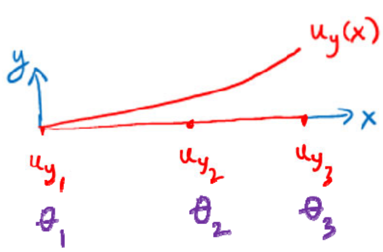
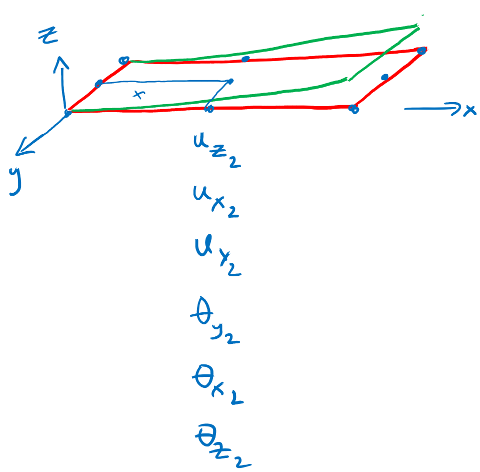
Euler-Bernoulli Beam Theory



$6 \times 9 = 54$

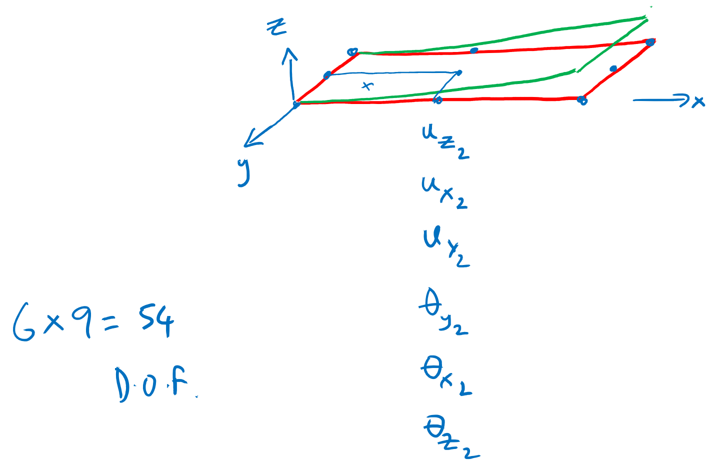
D.O.F.

Shell Theory

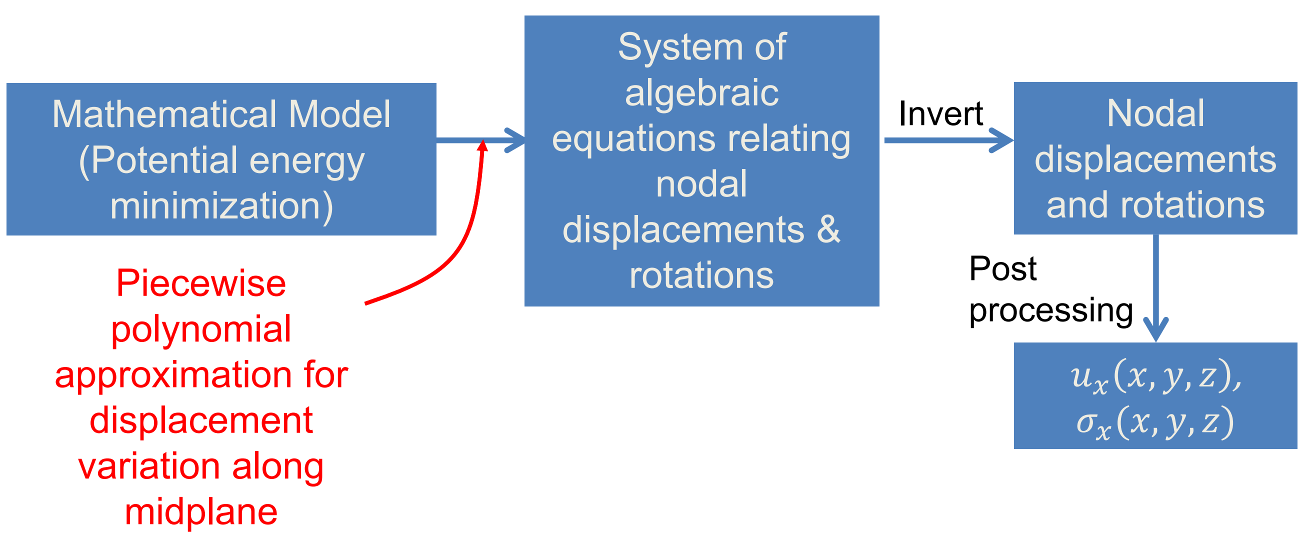


Derivation of Algebraic Equations

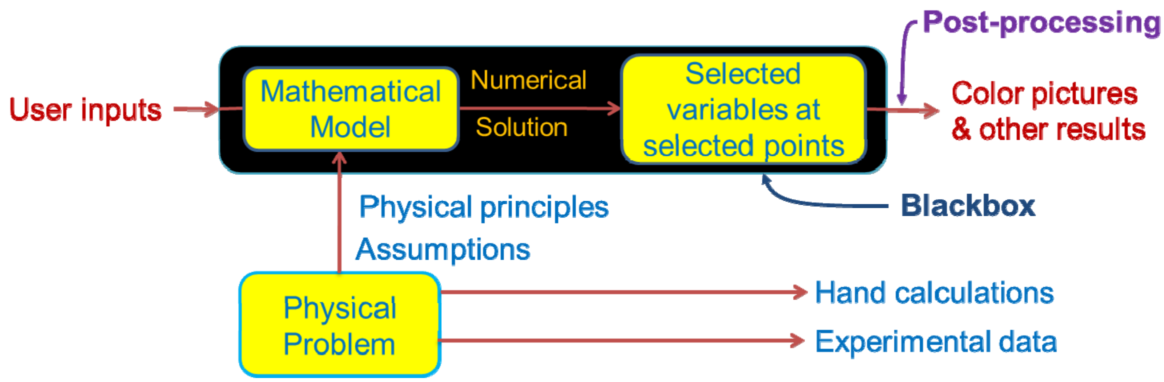
Shell Theory



Numerical Solution Strategy: Summary

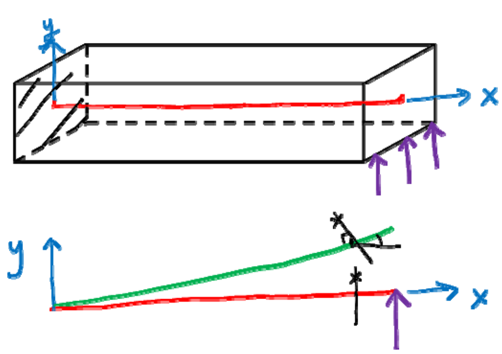


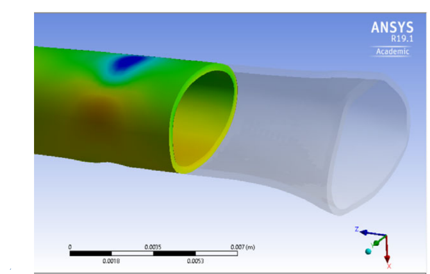
Pre-Analysis: Hand Calculations



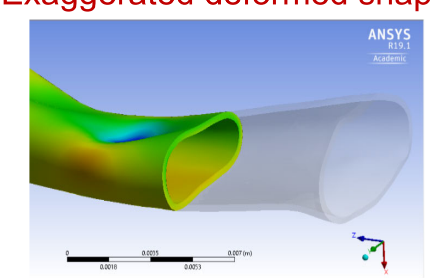
Euler-Bernoulli Beam Theory (Engrd 2020 Stuff)

- Assume plane sections remain plane
  - A plane section can only move up/down & rotate
  - Displacement in x-direction (u_x) at any cross-section increases linearly with y





Exaggerated deformed shape



Euler-Bernoulli Beam Theory (Continued)

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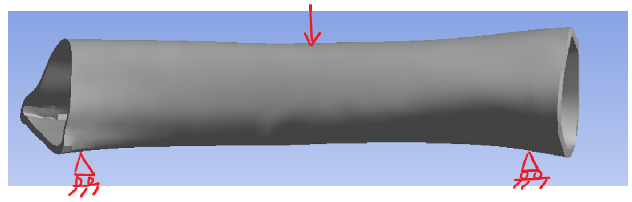
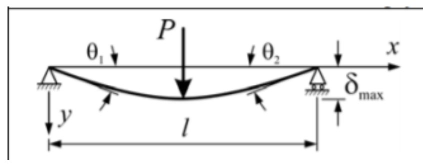
- Assume plane sections remain plane
  - A plane section can only move up/down & rotate
  - Displacement in x-direction (u_x) at any cross-section increases linearly with y
- Bending moment is known at any cross-section
- $\Rightarrow \sigma_x = -\frac{My}{I}$
  - ➢ Calcuate I & y by approximating geometry as hollow cylinder with constant cross-section
- $\sigma_x \rightarrow \epsilon_x \rightarrow u_y \rightarrow \delta_{max}$





$$\delta_{max} = \frac{Pl^3}{48EI}$$

ANSYS Steps

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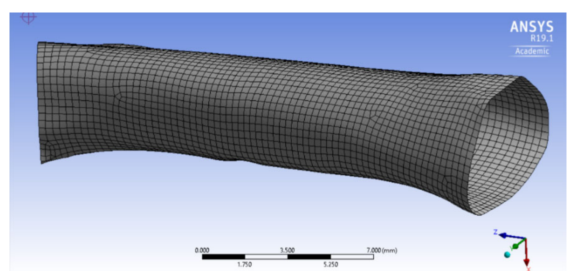
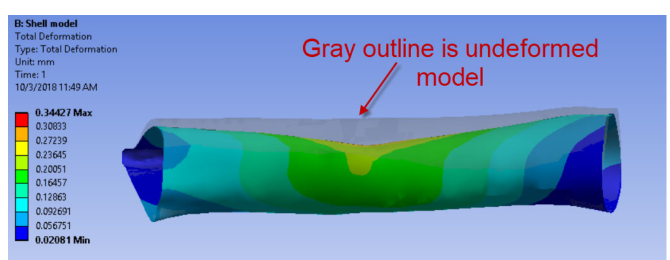
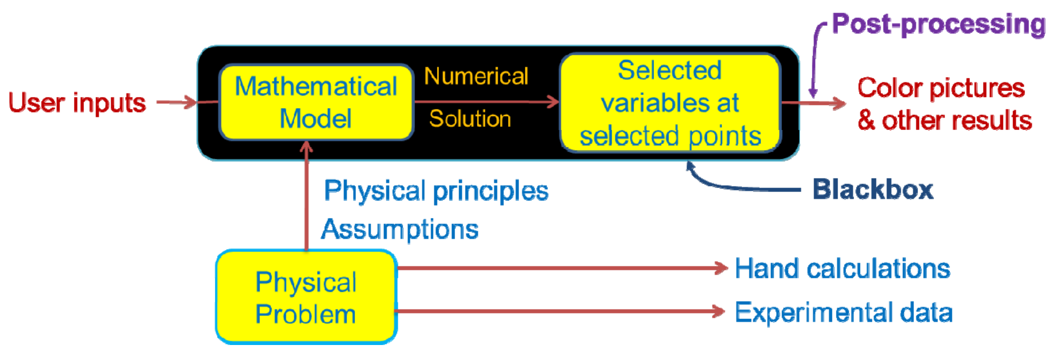
1. Geometry
   - CT Image > STL file > Smooth solid
2. Mesh
   - Specify element size
3. Model setup
   - Specify E, thickness
   - Specify boundary conditions
4. Numerical solution
   - Solve to obtain nodal displacements
5. Numerical results
   - Deformed shape
   - Reactions



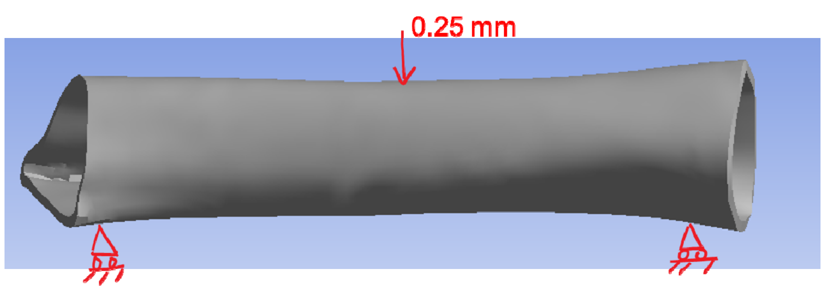


Verification & Validation



- Verification: Did I solve the model right?
  - Check consistency with mathematical model, level of numerical errors, comparison with hand calcs
- Validation: Did I solve the right model?
  - Check against experimental data

Verification & Validation: Typical Results



Deflection	Force (Sim)	Force (Hand calc)	Force (Expt)
0.25 mm	76 N	153 N	76 N