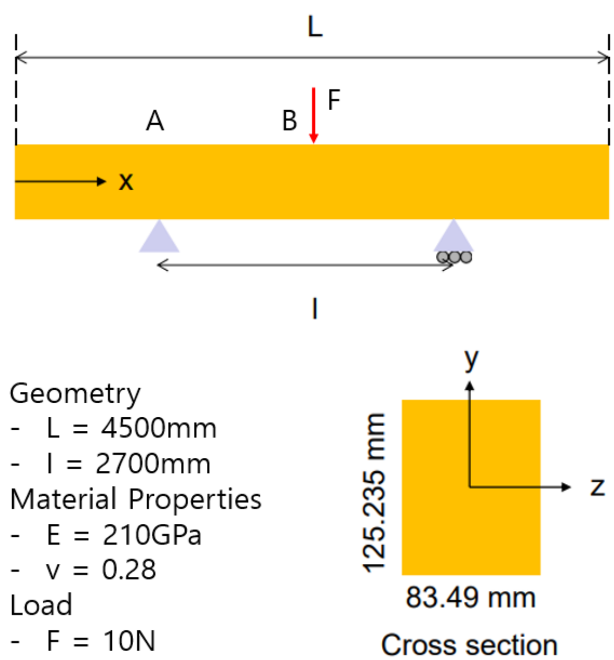
Submit the compressed file as `(ID)_(name).zip` to [ftp://cdl.hanyang.ac.kr → Undergraduate_CAE → lab → final] folder. It should contain the final results of each problem (equations and graphs) using PowerPoint (`ID.ppt`), COMSOL files (`problem#_#.mph`)

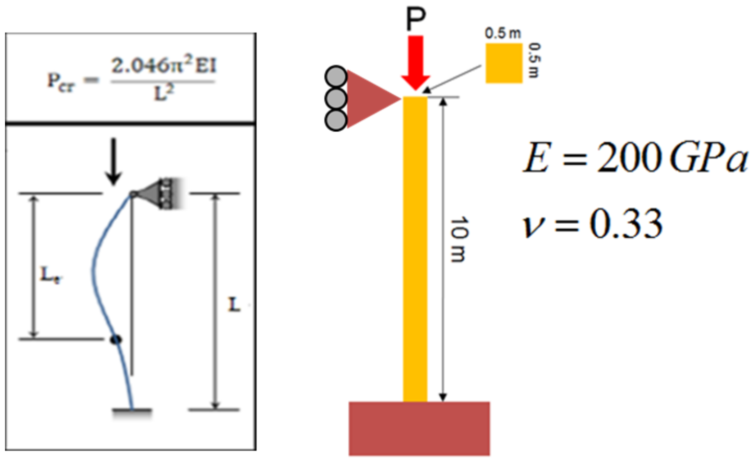
1. [PDE solving] Consider the following beam deflection problem. (Use **Normal** discretization level.) (20 pts total)



(1) Using 2D Beam module, compute deflection at point B and slope at point A. (10 pts)

(2) Using 2D Solids Mechanics module and symmetric condition, compute deflection at point B. (10 pts)

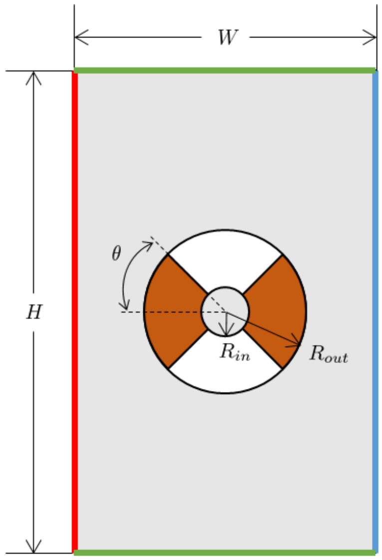
2. [Linear Buckling] For the column and boundary condition shown, compute critical loads for the column. (Use **Normal** discretization level.) (15 pts total)



(1) Use 2D Solid Mechanics module and show 3 mode shapes and each critical loads. (7 pts)

(2) Use 3D Solid Mechanics module and show 3 mode shapes and each critical loads. (8 pts)

3. [Heat Transfer]. Consider the following heat transfer problem. (Use **Fine** discretization level.) (35 pts total)



- **Material properties**
  - $k_{\text{agar}} = 0.56\ W/(m \cdot K)$
  - $k_{\text{PMMA}} = 0.22\ W/(m \cdot K)$
  - $k_{\text{copper}} = 430\ W/(m \cdot K)$

- **Dimensions**
  - $W = 50\ mm$
  - $H = 80\ mm$
  - $R_{in} = 4\ mm$
  - $R_{out} = 13.5\ mm$
  - $\theta = 45°$
  - $thickness = 1\ mm$
  - center of each circles $= (W/2, H/2)$

- **BCs**

  Dirichlet BC
  - $T_{Hot} = 314\ K$
  - $T_{Cold} = 273\ K$

  Neumann BC
  - $-\mathbf{n} \cdot \mathbf{q} = 0$

    where

    $\mathbf{n} =$ normal vector

    $\mathbf{q} = -k\nabla T$ (heat flux)

(1) Solve the Poisson equation using [Heat Transfer in Solids (ht)]. Then draw a x component total heat flux distribution along the [Cut Line 2D](0, H/2 → W, H/2) by [1D Plot Group / Line Graph] (15 pts)

(2) Solve the Poisson equation using [Weak Form PDE (w) (w)]. Then draw a x-component total heat flux distribution and relative error with solution (1) along the [Cut Line 2D](0, H/2 → W, H/2) by [1D Plot Group / Line Graph] (20 pts)

Hint)

Poisson equation

$$k\nabla^2\mathbf{T} - \mathbf{Q} = 0$$

$$\int_\Omega \left(k\nabla^2\mathbf{T} - \mathbf{Q}\right)\mathbf{v}\,d\Omega = 0$$

Integrate by part

$$\int_\Omega \nabla\cdot\left(k\mathbf{v}\nabla\mathbf{T}\right)d\Omega + \int_\Omega \left(k\nabla\mathbf{v}\cdot\nabla\mathbf{T}\right)d\Omega - \int_\Omega \mathbf{Q}\mathbf{v}\,d\Omega = 0$$

Divergence Theorem

$$\int_{\partial\Omega} \left(k\mathbf{v}\nabla\mathbf{T}\right)\cdot\mathbf{n}\,d\partial\Omega + \int_\Omega \left(k\nabla\mathbf{v}\cdot\nabla\mathbf{T}\right)d\Omega - \int_\Omega Q\mathbf{v}\,d\Omega = 0$$

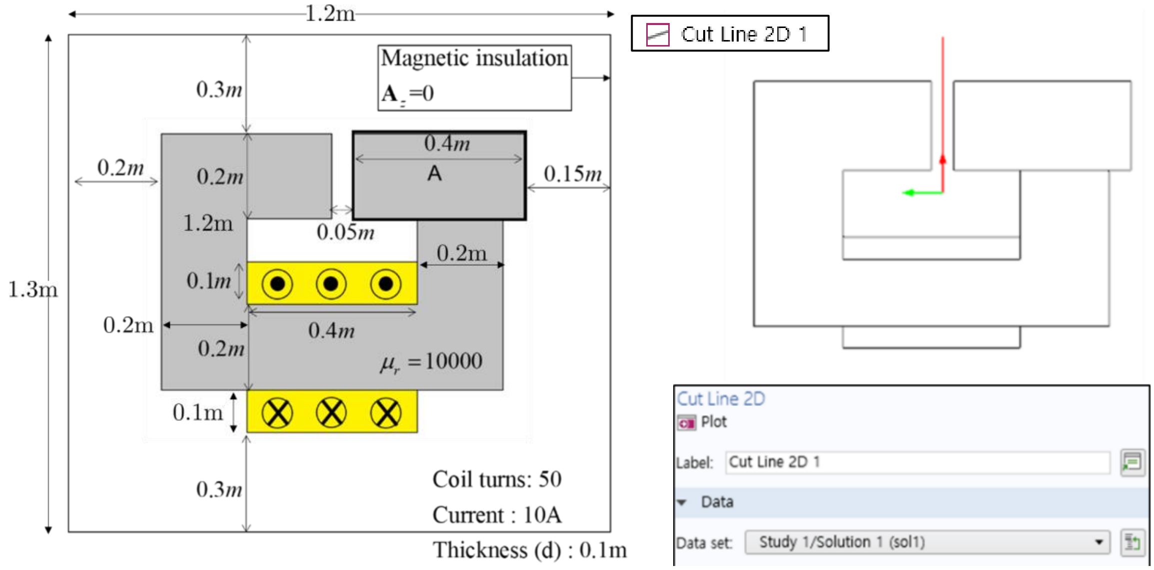
Boundary Condition($-\mathrm{k}\nabla\mathbf{T} = 0$)

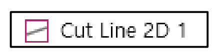
$$\int_\Omega \left(k\nabla\mathbf{v}\cdot\nabla\mathbf{T}\right)d\Omega - \int_\Omega Q\mathbf{v}\,d\Omega = 0 \text{(Weak form)}$$

$$\text{relative error} = \frac{abs(sol - ref)}{abs(ref)} * 100\%$$

4. [Magnetic Actuator] For the actuator and boundary conditions shown, solve the Poisson equation by 

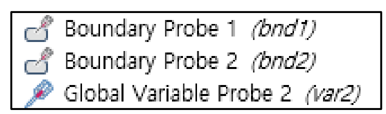
. (Use **Fine** discretization level.) (30 pts total)



1) Draw a Magnetic flux density norm distribution along the 

by 

(15 pts total)

2) Evaluate the magnetic force using Maxwell stress tensor method by 

(15 pts total) Analytic solution : 1.4289 N

Hint:

Magnetic force (Maxwell Stress Tensor Method)

$$f_x = \frac{d}{\mu_0}\left[\int \frac{B_x B_x}{2} dy + \int B_x B_y dx\right]$$

d : thickness

μ_0 : vaccum permeability

B : flux density

f : force