Solid Mechanics (mode/linear buckling)

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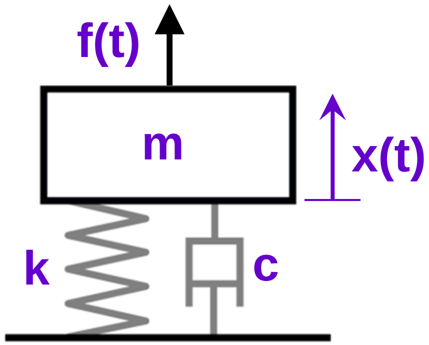
CONTENTS

- Modal Analysis
    - Beam, solid
- Linear Buckling
    - Column, panel
- Assignment

MODAL ANALYSIS (1)

- Motion equation of single DOF system



$$m\ddot{x} + c\dot{x} + kx = f(t)$$

$m\ddot{x}$	**Inertial Force**
$c\dot{x}$	**Damping Force**
kx	**Elastic Force**

- Eigenvalue analysis

$$[M]\{\ddot{x}\} + [K]\{x\} = 0$$

$$\boxed{\left([K] - \omega^2[M]\right)\{\Phi\} = 0 \;\rightarrow\; \det\left([K] - \omega^2[M]\right) = 0}$$

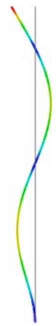
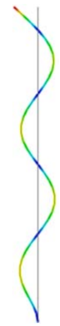
ω^2: eigenvalue ω: eigenfrequency $\{\Phi\}$: eigen vector

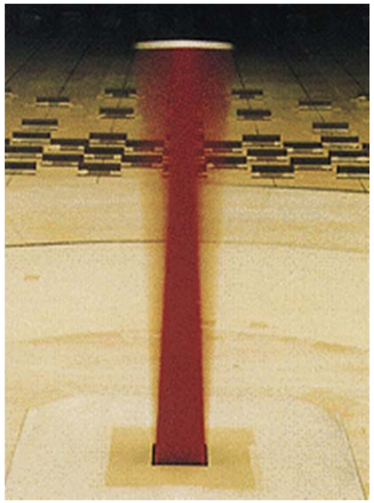
Max. inertial force

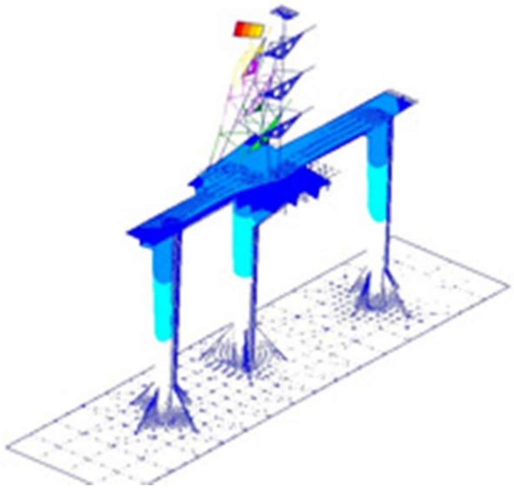
Max. elastic force

MODAL ANALYSIS (1)

- Mode shape (eigen vector)

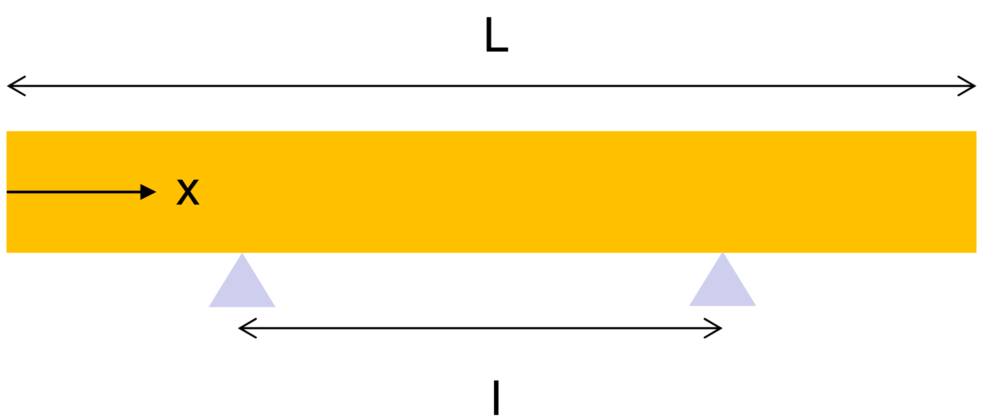
Mode	1	2	3	4	5
Mode shape					
Eigenfrequency [Hz]	**102.2**	640.1	1790.9	3505.7	5787.0





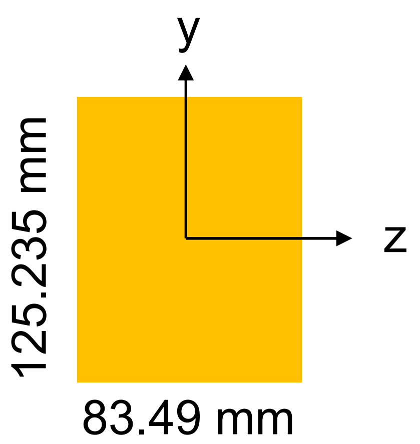
SIMPLY SUPPORTED BEAM

- Eigenfrequency analysis (2D beam VS. 3D solid)



Geometry
- L = 4550 mm
- l = 2700 mm

Material : alloy steel
- E = 210 GPa
- v = 0.28
- ρ = 1.519e-5 kg/mm^3



Cross section

ANALYTIC SOLUTION

$$K = \frac{48EI}{l^3} = 7000 \text{ N/mm}$$

$$\rightarrow I = \frac{Kl^3}{48E} = \frac{7000 \times 2700^3}{48 \times 210000} = 1.367e^7 \text{ mm}^4$$

1st natural frequency

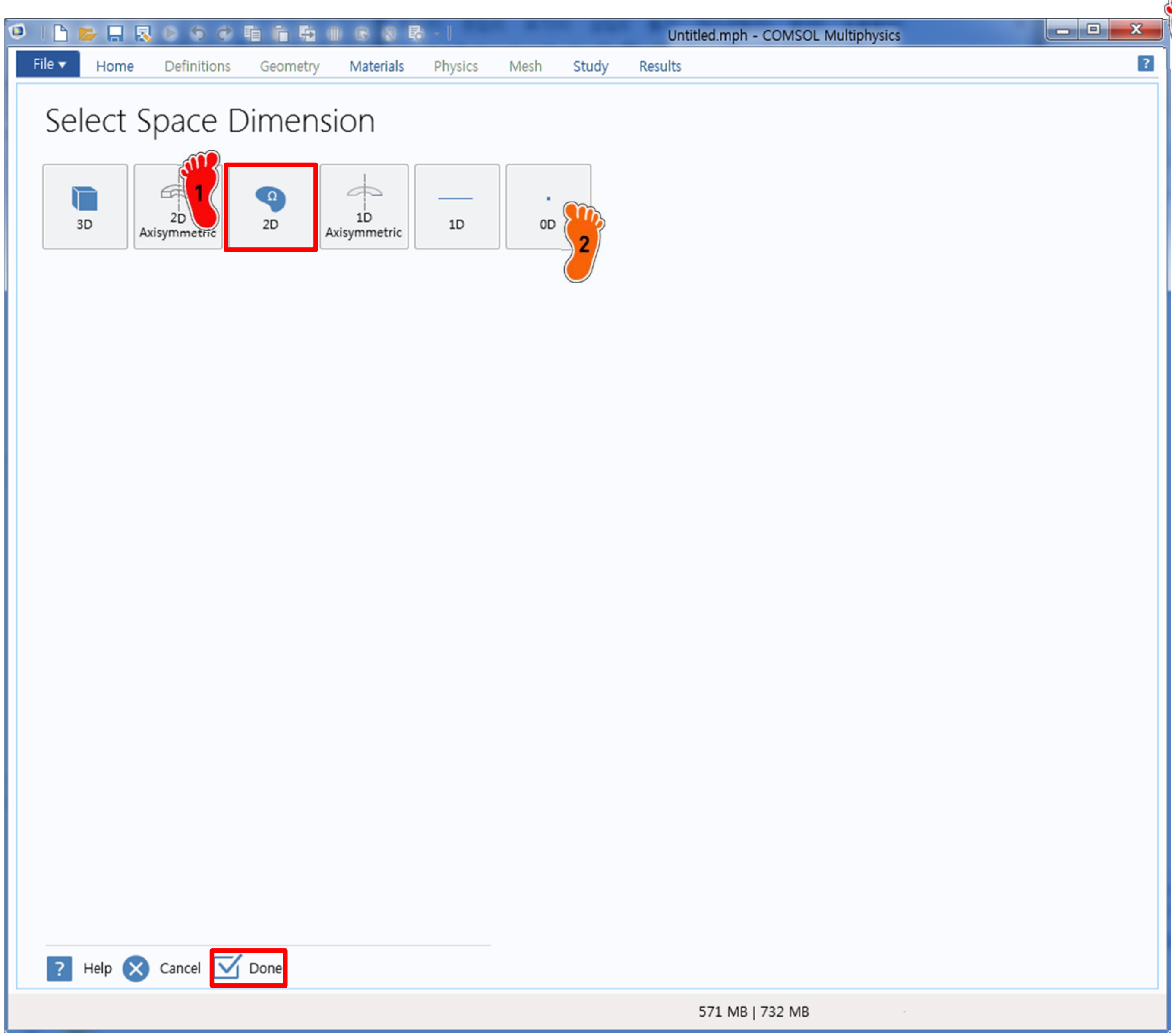
$$\omega_n = 22.4L^{-(3/2)}\sqrt{\frac{EI}{M}}$$

$$= 22.4 \times \left(\frac{1}{4550[\text{mm}]}\right)^{1.5}\sqrt{\frac{210000\left[\text{N/mm}^2\right] \times 1.367e^7\left[\text{mm}^4\right]}{723[\text{kg}]}}$$

$$= 22.4 \times \left(\frac{1}{4550[\text{mm}]}\right)^{1.5}\sqrt{\frac{210000000\left[\text{kg/mm}\cdot\text{s}^2\right] \times 1.367e^7\left[\text{mm}^4\right]}{723[\text{kg}]}}$$

$$= 145.392 \text{ rad/s} \rightarrow f = \frac{\omega}{2\pi} = 23.14 \text{ Hz}$$

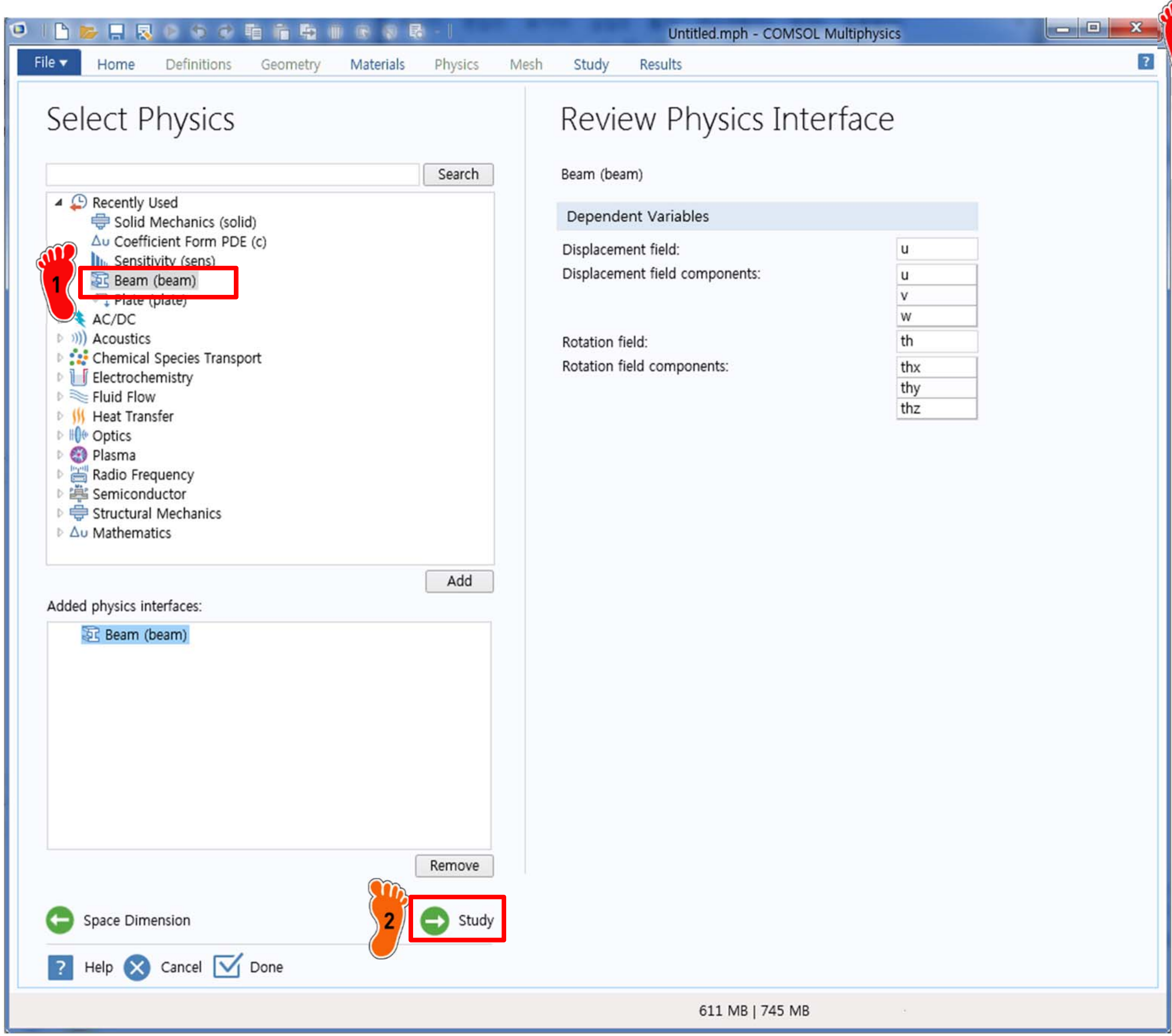
DIMENSION SELECTION



1 2D 선택

2 Done 클릭

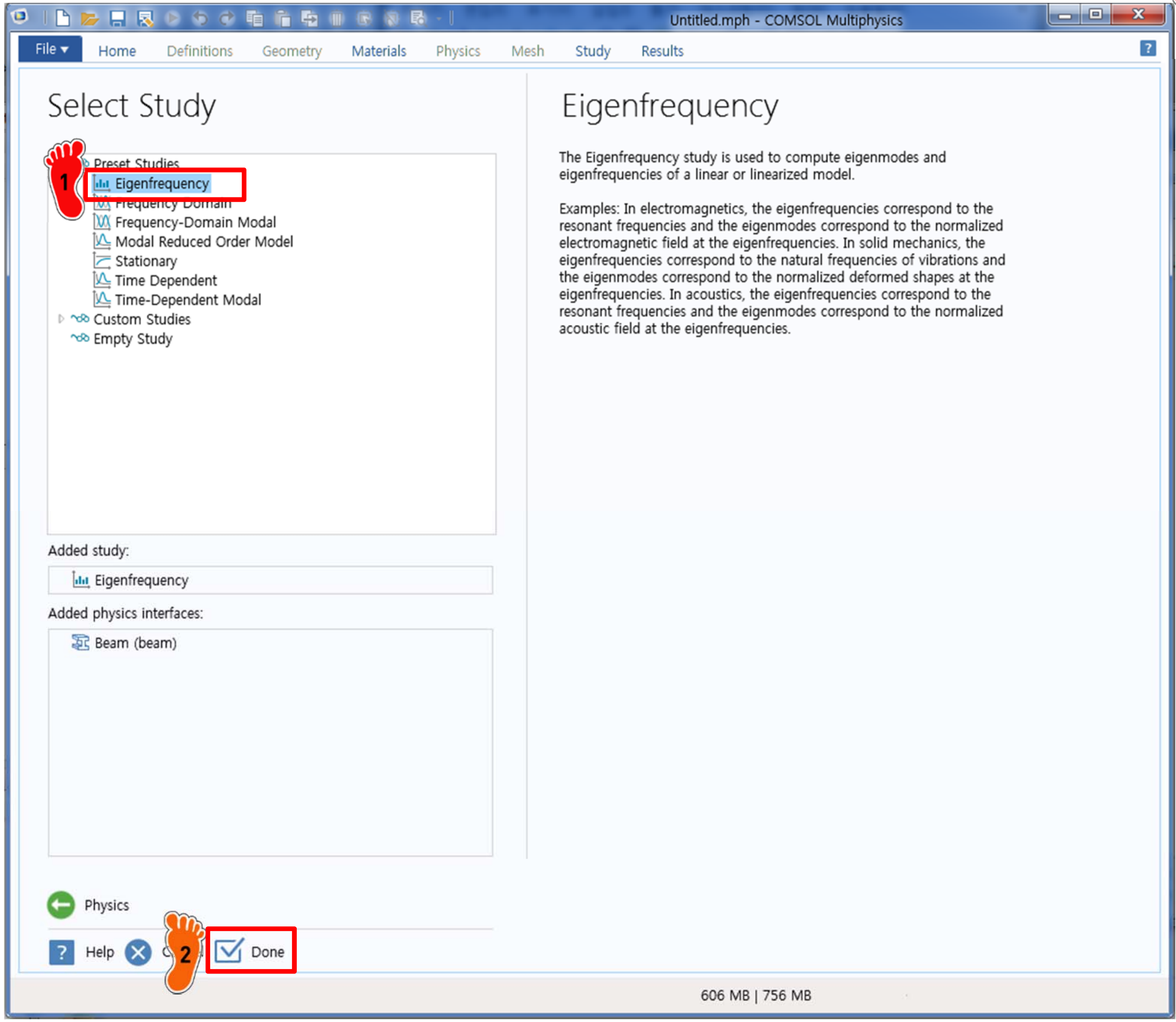
PHYSICS SELECTION



1 Structural Mechanics 의 Beam 선택

2 Study 클릭

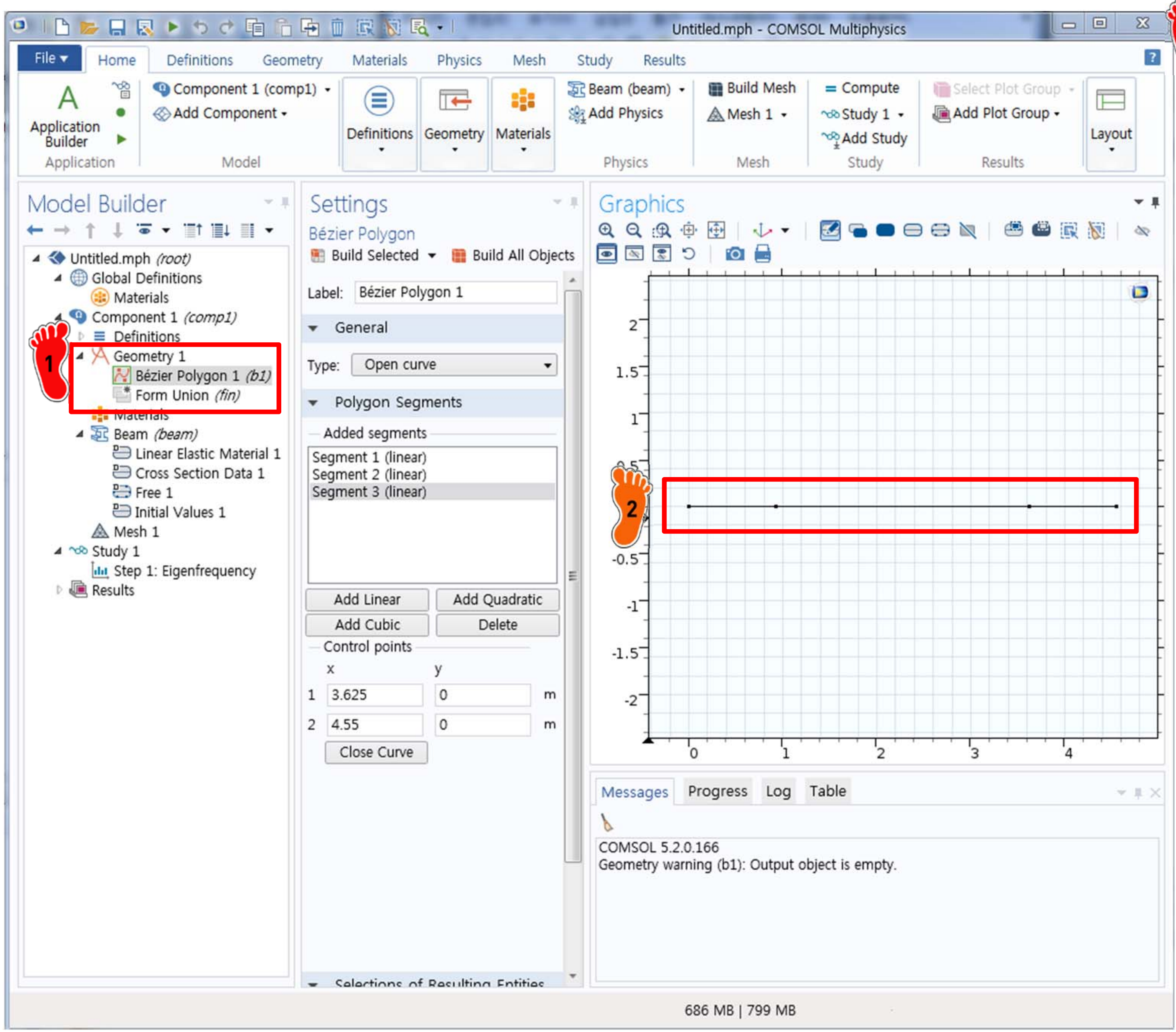
STUDY TYPE SELECTION



1 Eigenfrequency 선택

2 Done 클릭

GEOMETRY CREATION

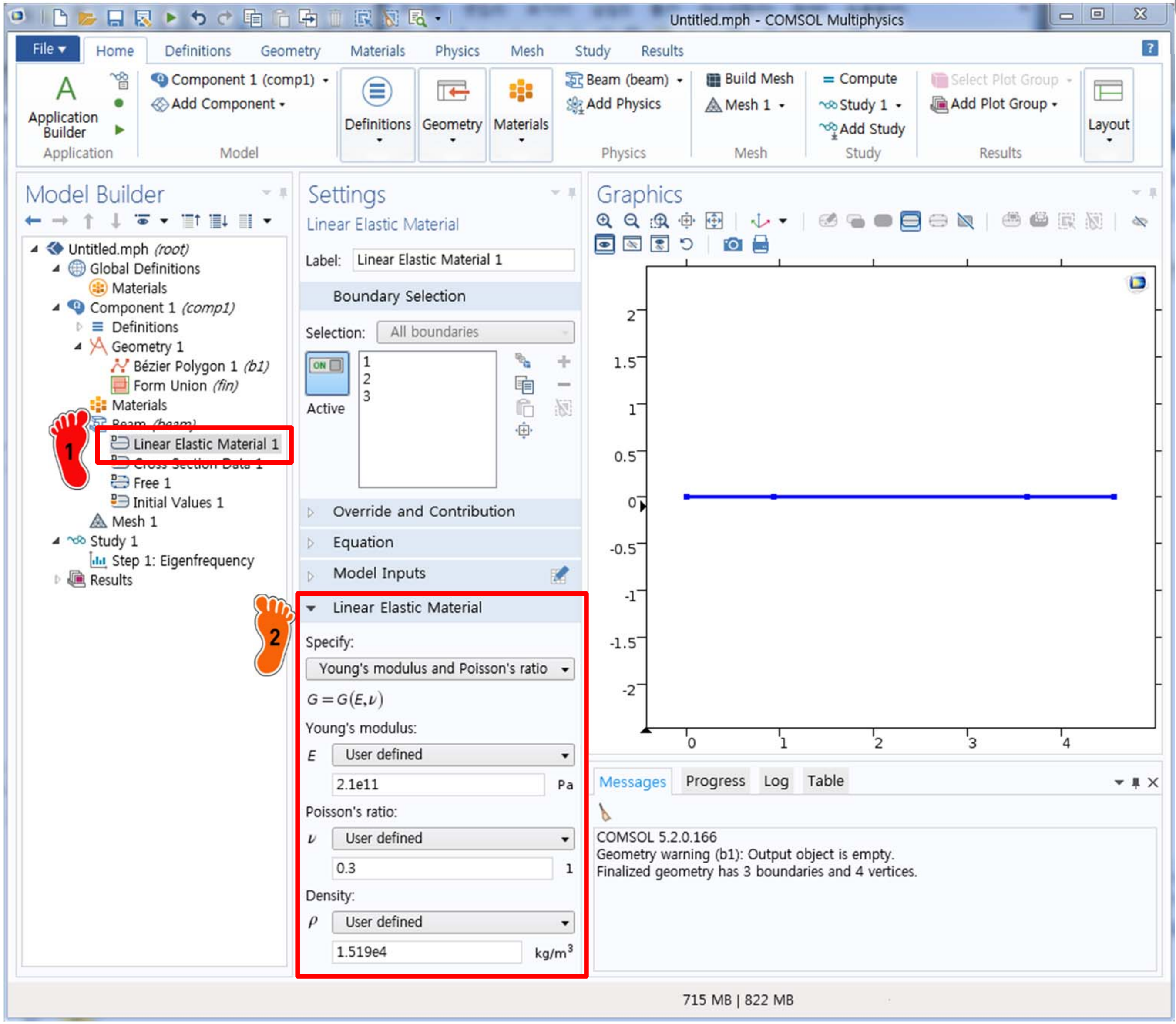


1 Bezier polygon을 생성 (Type : open curve)

2 기하형상 생성

(0,0) (0.925,0)
(3.625,0) (4.55,0)

MATERIAL PROPERTY

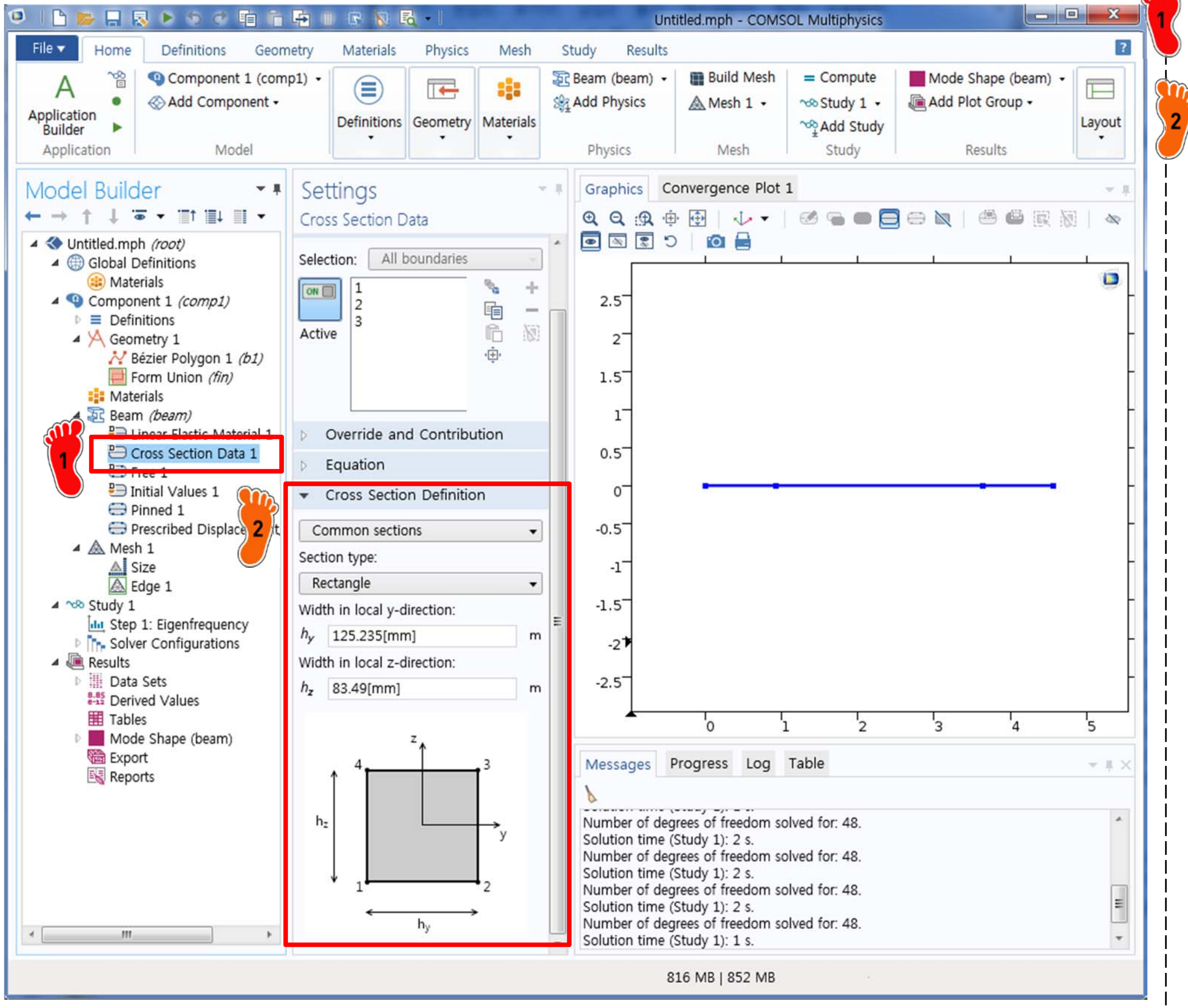


1 Linear Elastic Material 클릭

2 E: 2.1e11
mu: 0.3
rho : 1.519e4

입력

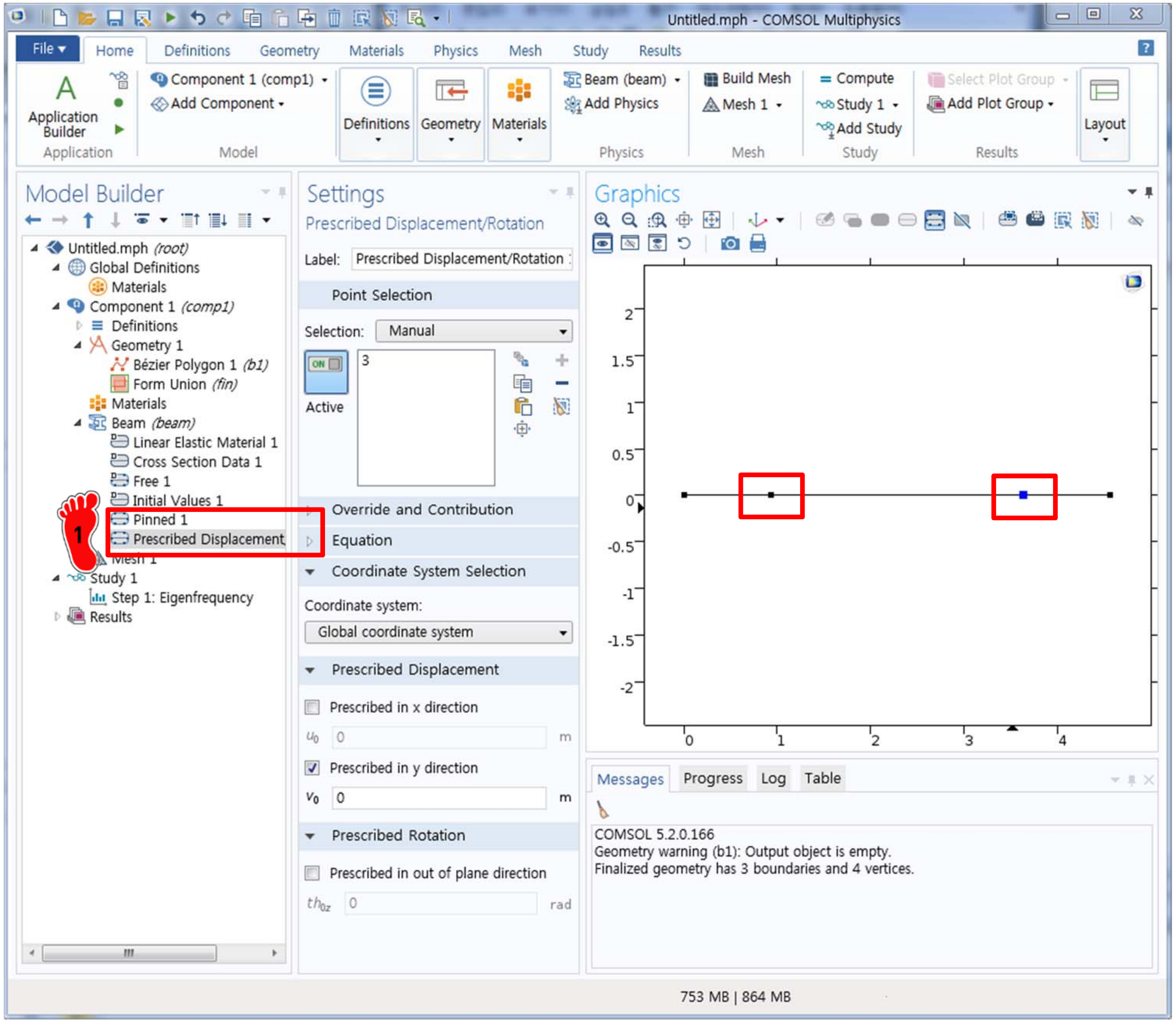
CROSS SECTION DATA



1 Cross Section Data클릭

2 hy = 125.235 [mm]
hz = 83.49 [mm]
입력

BOUNDARY CONDITION



1

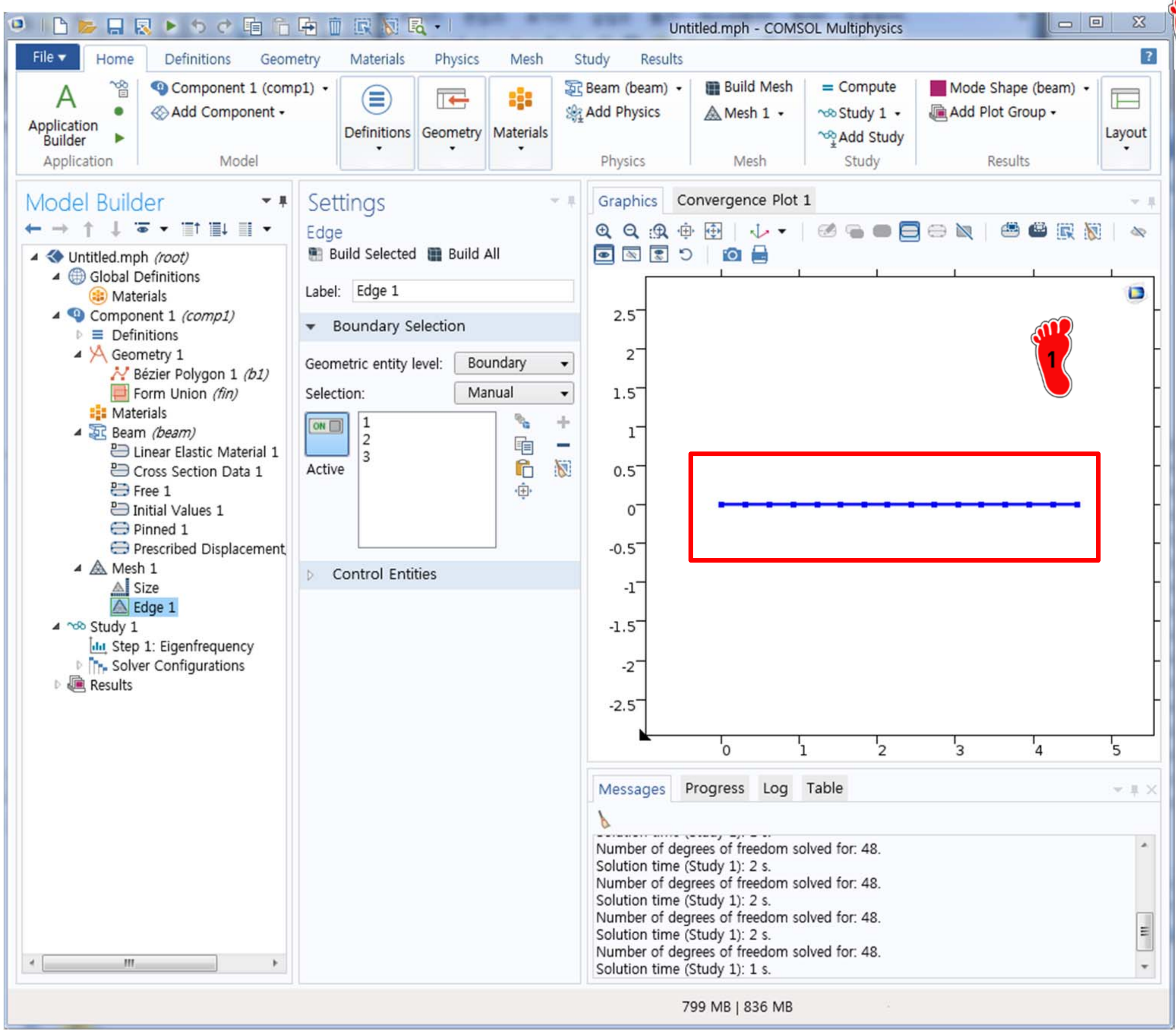
Pinned
Prescrived Displacement
경계조건 생성

Pinned : point 2
Fixed in y direction: point 3

2

3

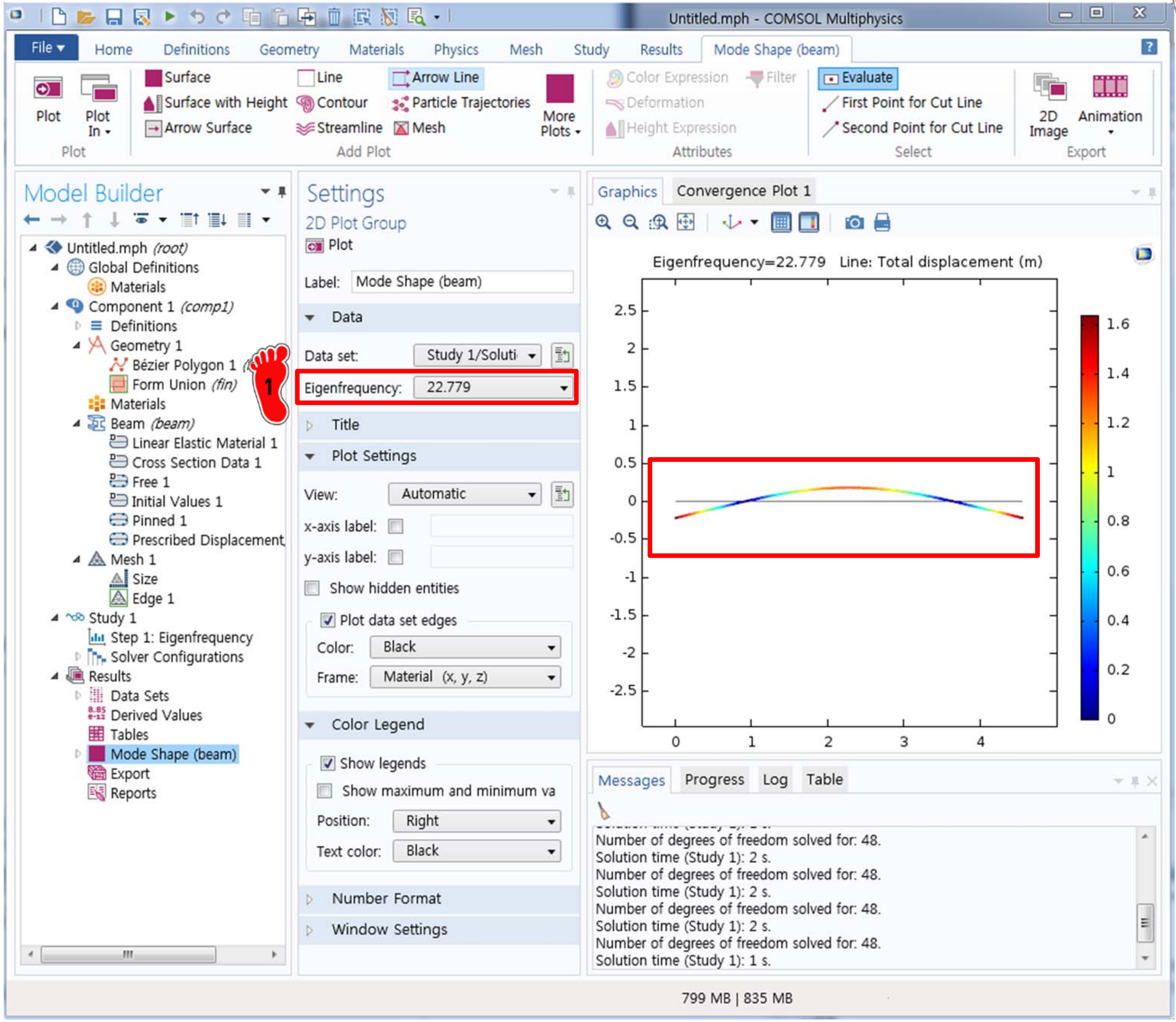
MESH



Edge element 기능을 이용하여 요소 생성

그 후, 해석실행

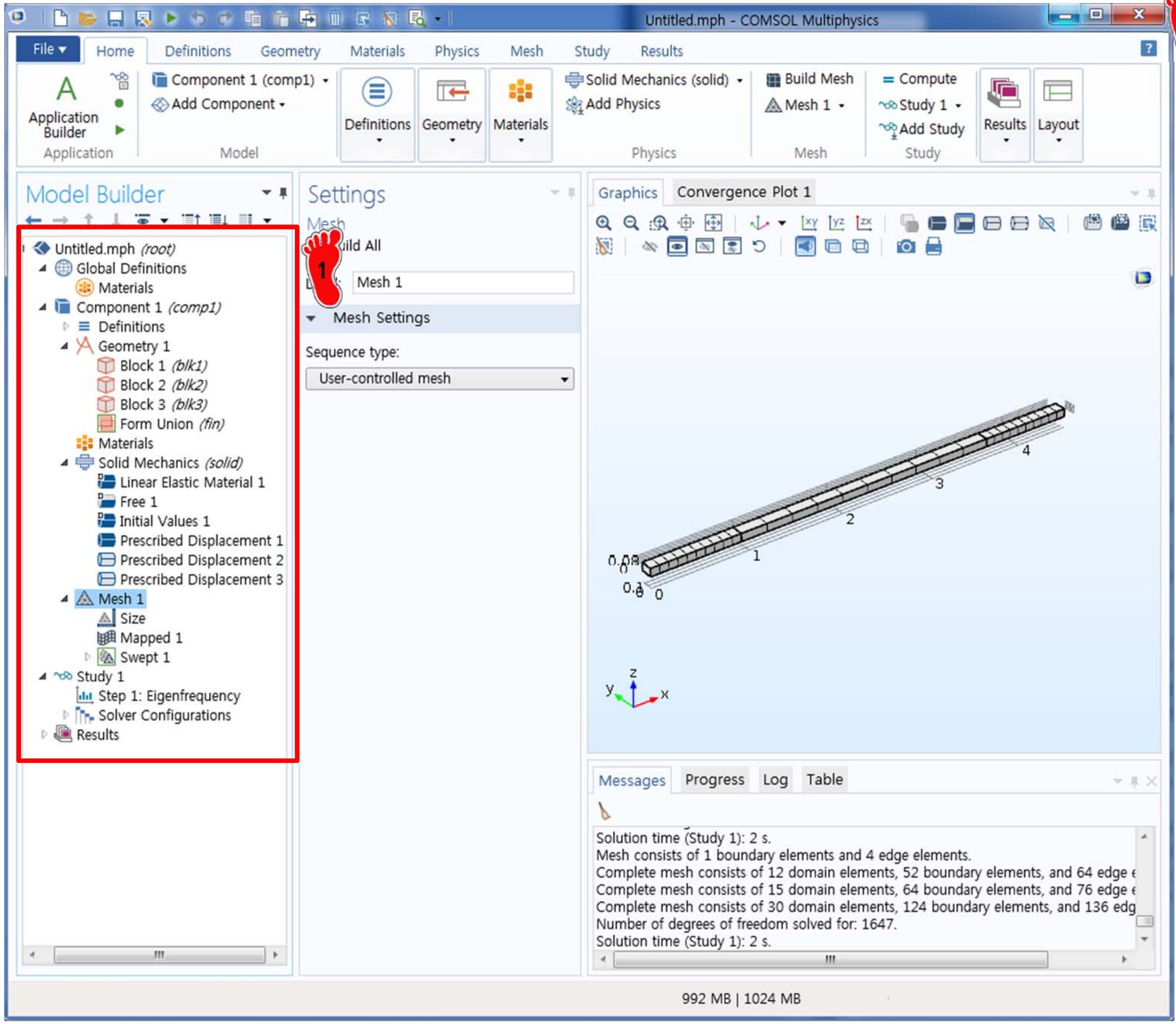
POST-PROCESSING



Eigenfrequency에 대한 모드형상확인

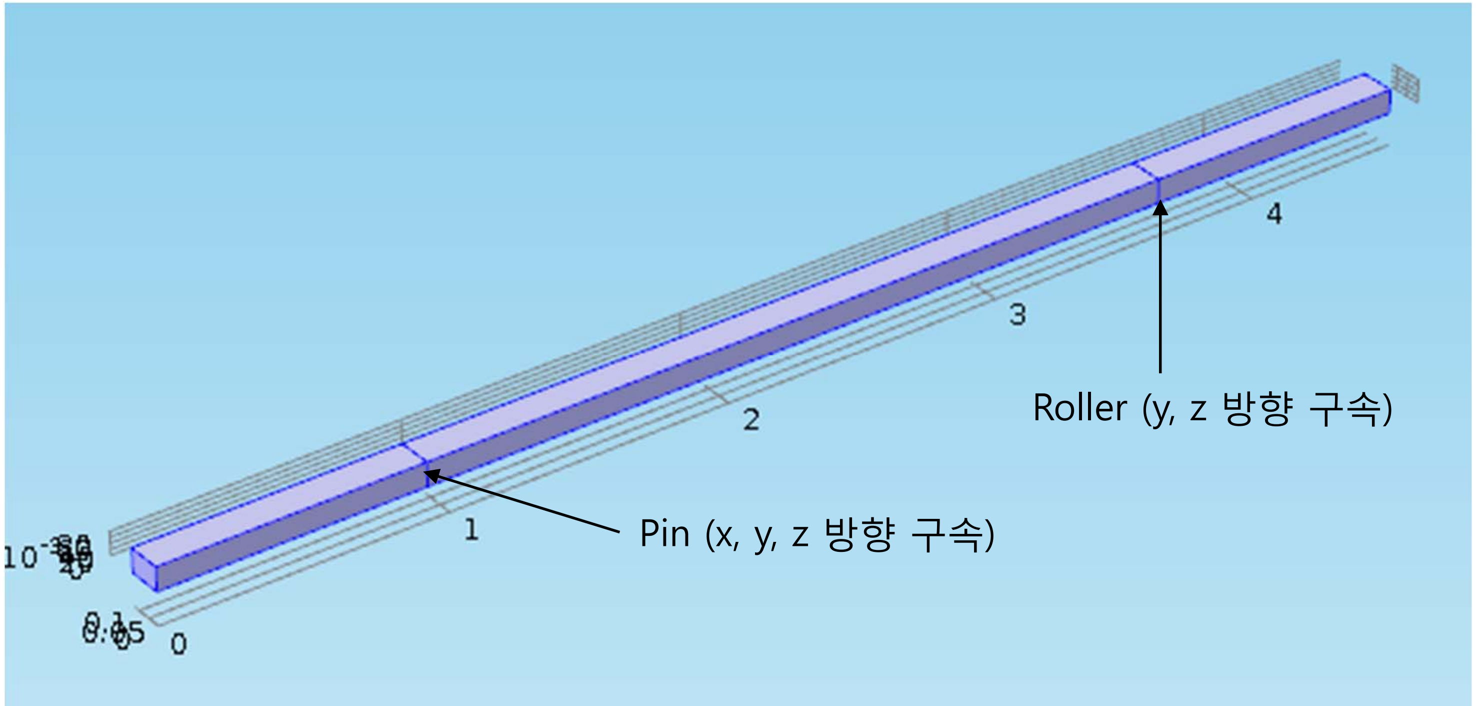
1차: 22.78 Hz

3D SOLID MODELING



1 문제에 맞는 기하형상 생성, 물성치 입력

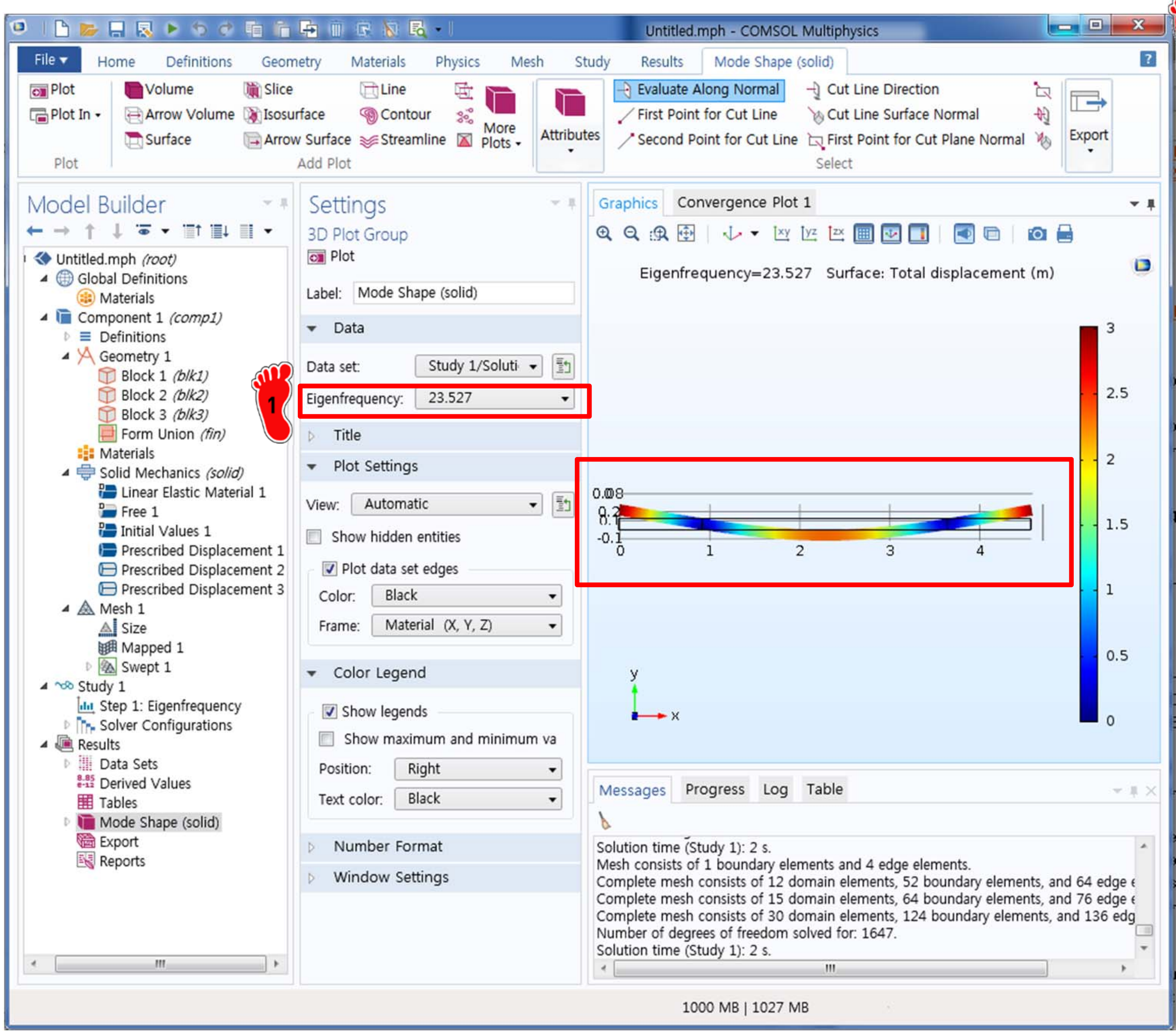
BOUNDARY CONDITIONS



- ❖ 2D beam model과 같은 모드 형상을 얻기 위해,

  모든 soild 컴포넌트의 z방향 변위 구속

POST-PROCESSING



1 해석 실행 후, Eigenfrequency에 대한 모드형상확인

1차: 23.53 Hz

SUMMARY

모드 차수	1차	2차	3차
해석적인 해 [Hz]	23.14		
모드 형상 (빔 요소)			
주파수 [Hz]	22.78	48.76	75.72
모드 형상 (솔리드 요소)			
주파수 [Hz]	23.53	50.13	78.14

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- Modal Analysis
  - Beam, solid
- <u>Linear Buckling</u>
  - <u>Column, panel</u>
- Assignment

COLUMN BUCKLING

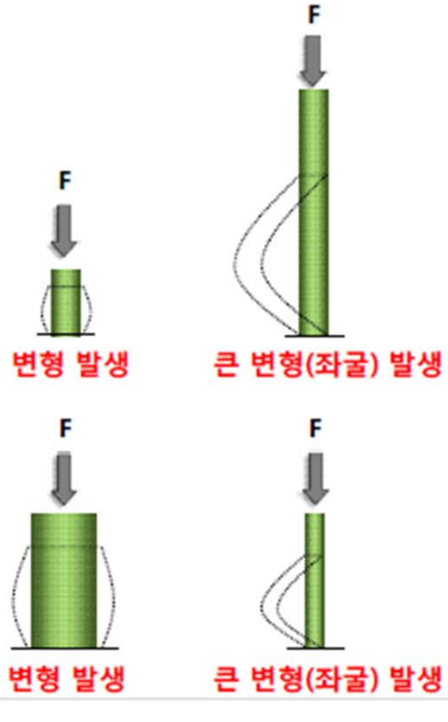
좌굴 해석

- 좌굴해석은 압축력을 받는 구조물의 불안정성 여부를 판단하기 위한 해석이다.
- 좌굴에 의한 구조물의 불안정성은 재료 강도에 무관하고, 구조물의 기하학적 형상 및 강성, 구속 조건과 밀접관 관련이 있다.
- 가늘고 긴 구조물 끝에 구조물 축 방향으로 압축력이 작용하는 경우, 하중의 크기가 작을 때에는 하중의 크기에 비례하여 구조물이 압축변형을 하지만, 특정 크기 이상의 하중이 작용하면 좌굴이 발생하여 하중의 크기가 증가하지 않아도 구조물이 크게 변형을 일으키게 된다.

원기둥의 좌굴 형상

A. 길이가 다르고 면적이 같은 원기둥에 같은 크기의 압축력을 받는 경우

B. 면적은 다르고 길이는 같은 원기둥에 같은 크기의 압축력을 받는 경우



- A의 경우에는 두 원기둥의 면적이 같기 때문에 σ=F/A 공식에 의해 발생하는 응력크기가 같다.
  하지만 기둥의 길이가 길어진 경우에는 큰 변형(좌굴)이 발생할 수 있다.

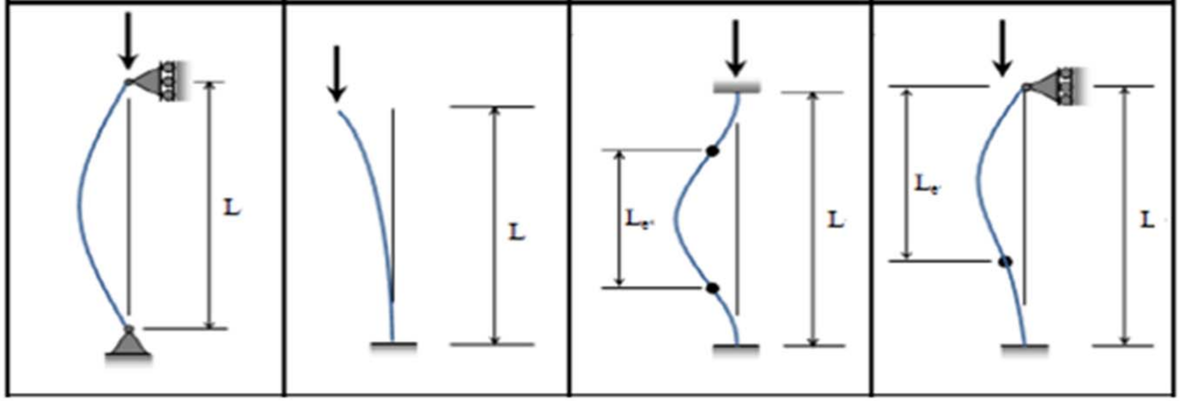
- B의 경우에는 두 원기둥의 길이는 같지만 면적이 다르기 때문에 동일한 압축력을 가하게 되면 면적이 작은 쪽에서 더 큰 응력을 받기 때문에 좌굴이 발생하게 된다.
  즉, 원기둥의 면적이 작을수록(압축응력이 클수록), 길이가 길수록 좌굴이 발생할 확률이 높아진다.

COLUMN BUCKLING

하중/경계 조건

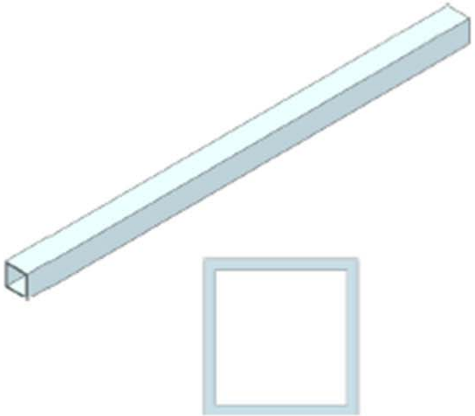
- 하중은 주로 가늘고 긴 구조물의 축방향에 대한 압축력을 가하는 경우가 일반적이며, 하중을 입력 하는 방식은 선형 정적 해석의 경우와 동일하다.
- 좌굴 해석에서의 경계조건 역시 선형 정적 해석에서의 경계조건 입력 방법과 동일하다.
- 단, 구조물의 좌굴 하중은 부재의 구속 조건에 따라 상당히 달라지므로 구속의 성분은 좌굴을 고려하여 합리적으로 설정할 필요가 있다.

양단 핀지지	상단자유, 하단고정	양단 고정	상단핀지지, 하단고정
$P_{cr} = \frac{\pi^2 EI}{L^2}$	$P_{cr} = \frac{\pi^2 EI}{4L^2}$	$P_{cr} = \frac{4\pi^2 EI}{L^2}$	$P_{cr} = \frac{2.046\pi^2 EI}{L^2}$



COLUMN BUCKLING

임계하중의 계산



$$P_{cr} = EI\alpha^2, \alpha = \frac{\pi}{L}\left(\frac{1}{2} + k\right), k = 0, 1, 2, 3, \ldots$$

단면 : $150mm \times 150mm$

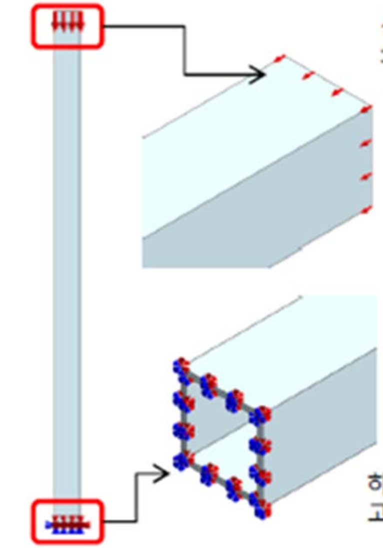
두께 (t) : $10mm$

길이 (L) : $3000mm$

$P = 160\ kN$

$E = 70\ GPa$

$\nu = 0.33$

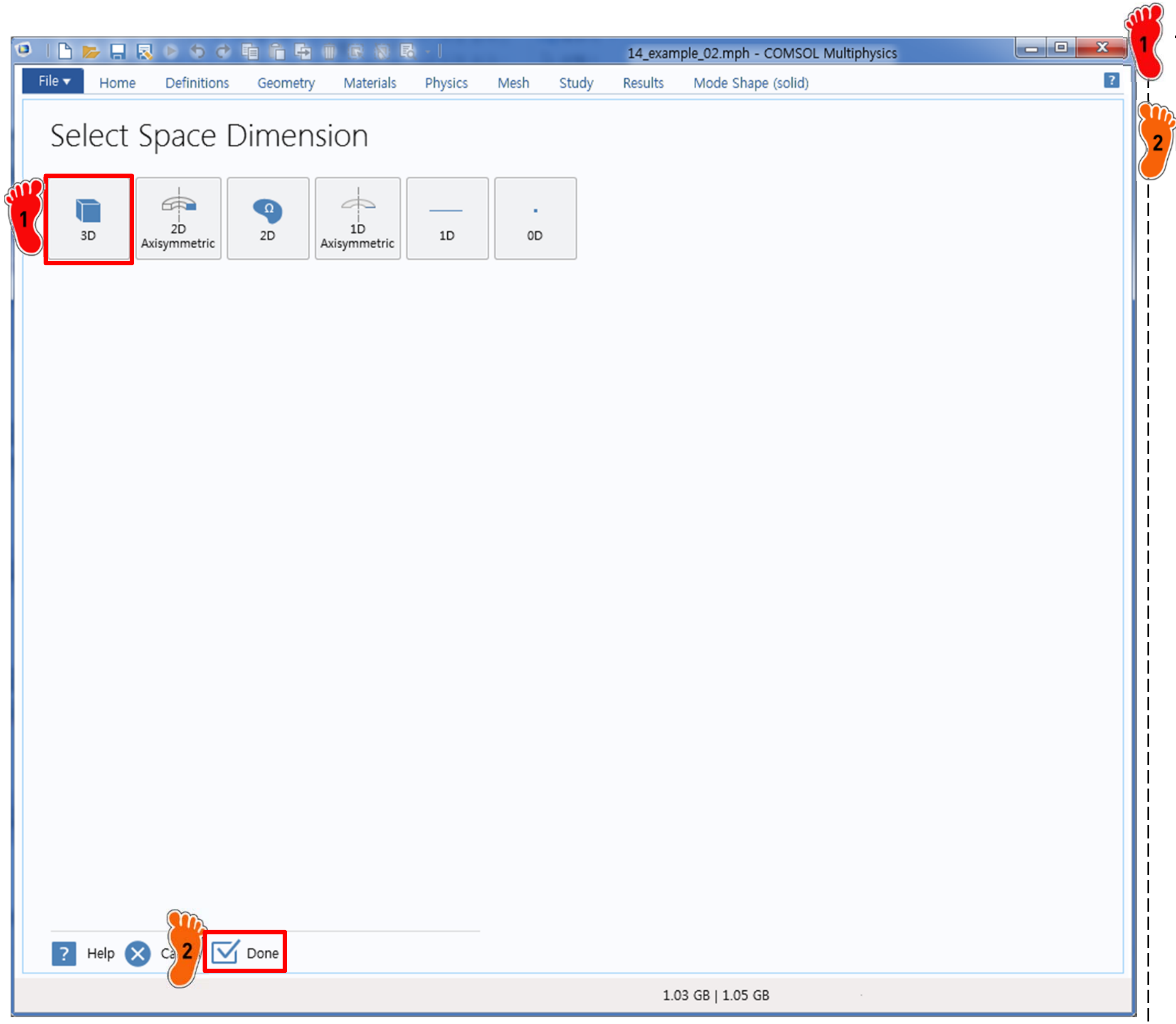


$P_1 = 352.9$ kN

$P_2 = 3176$ kN

$P_3 = 8821$ kN

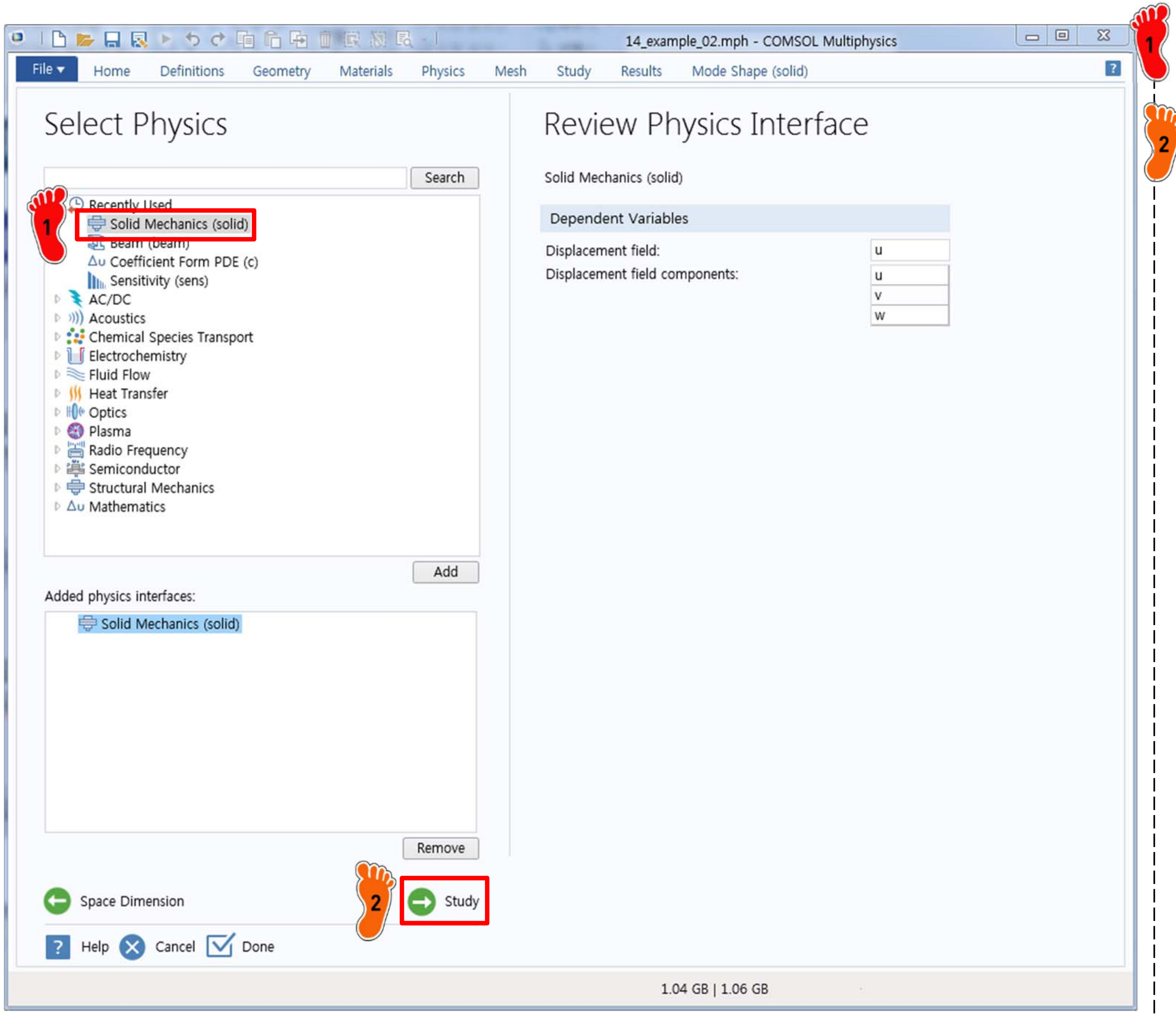
DIMENSION SELECTION



1 3D 선택

2 Done 클릭

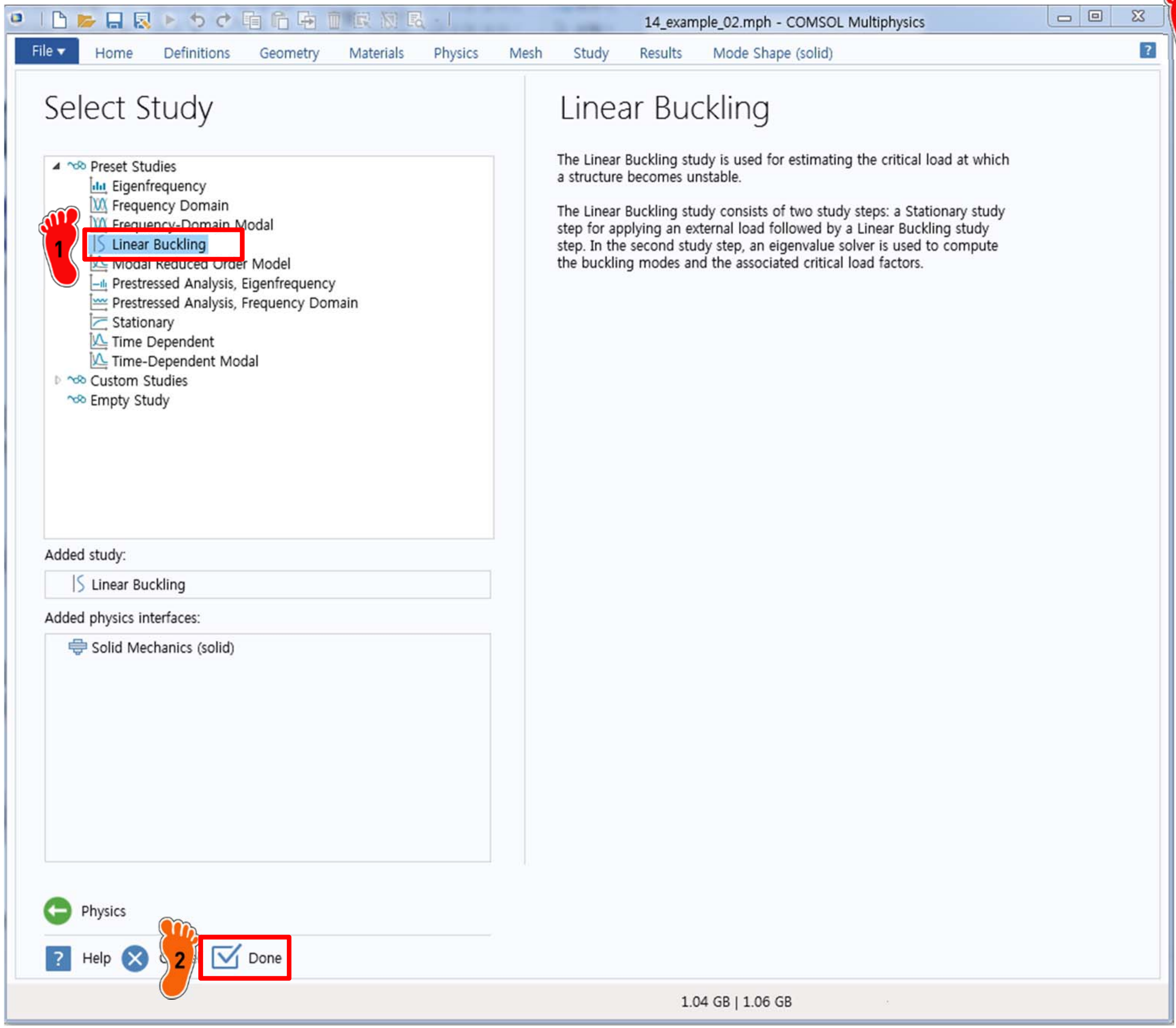
PHYSICS SELECTION



1 Structural Mechanics 의 Solid Mechanics 선택

2 Study 클릭

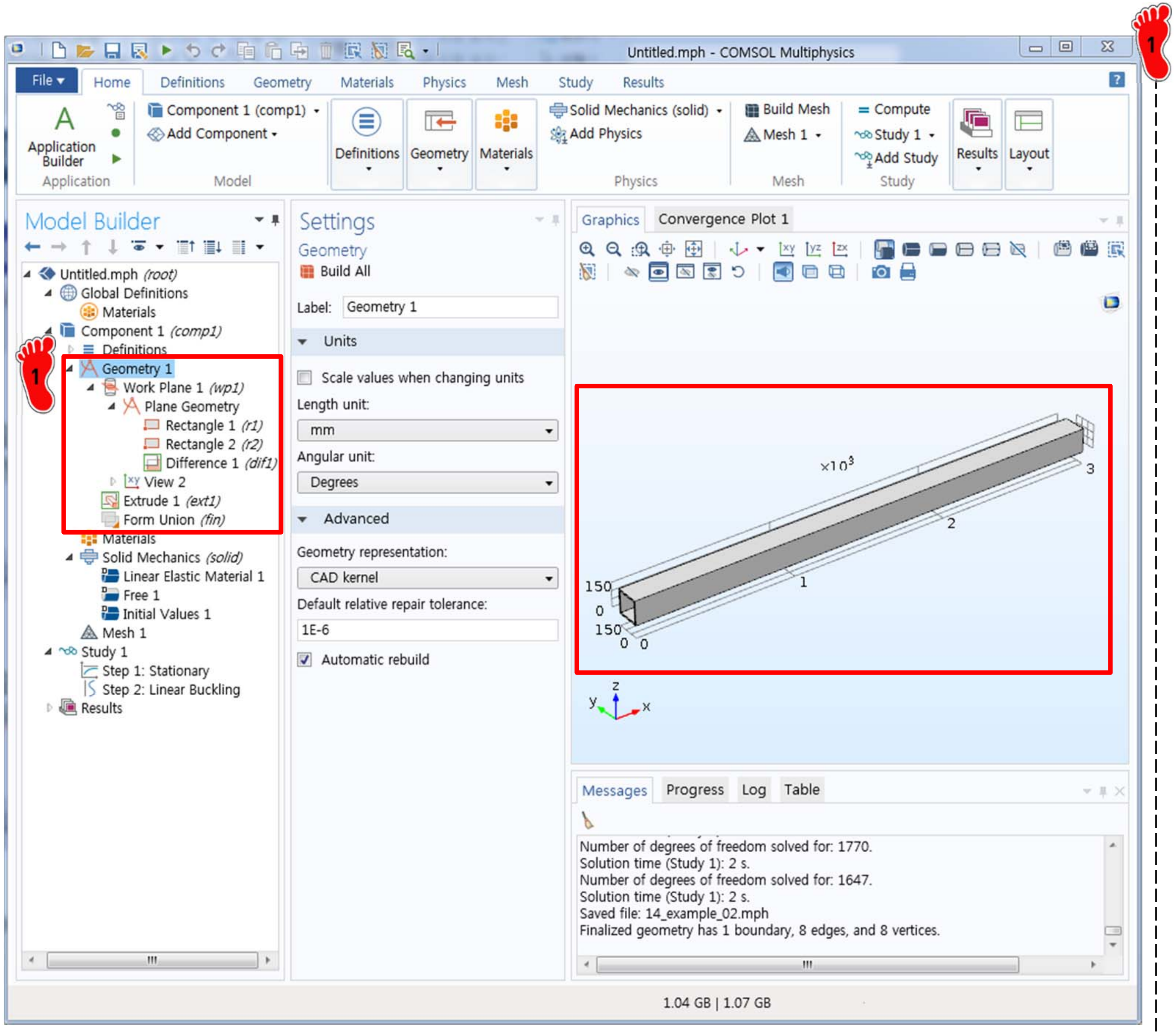
STUDY TYPE SELECTION



1 Linear Buckling선택

2 Done 클릭

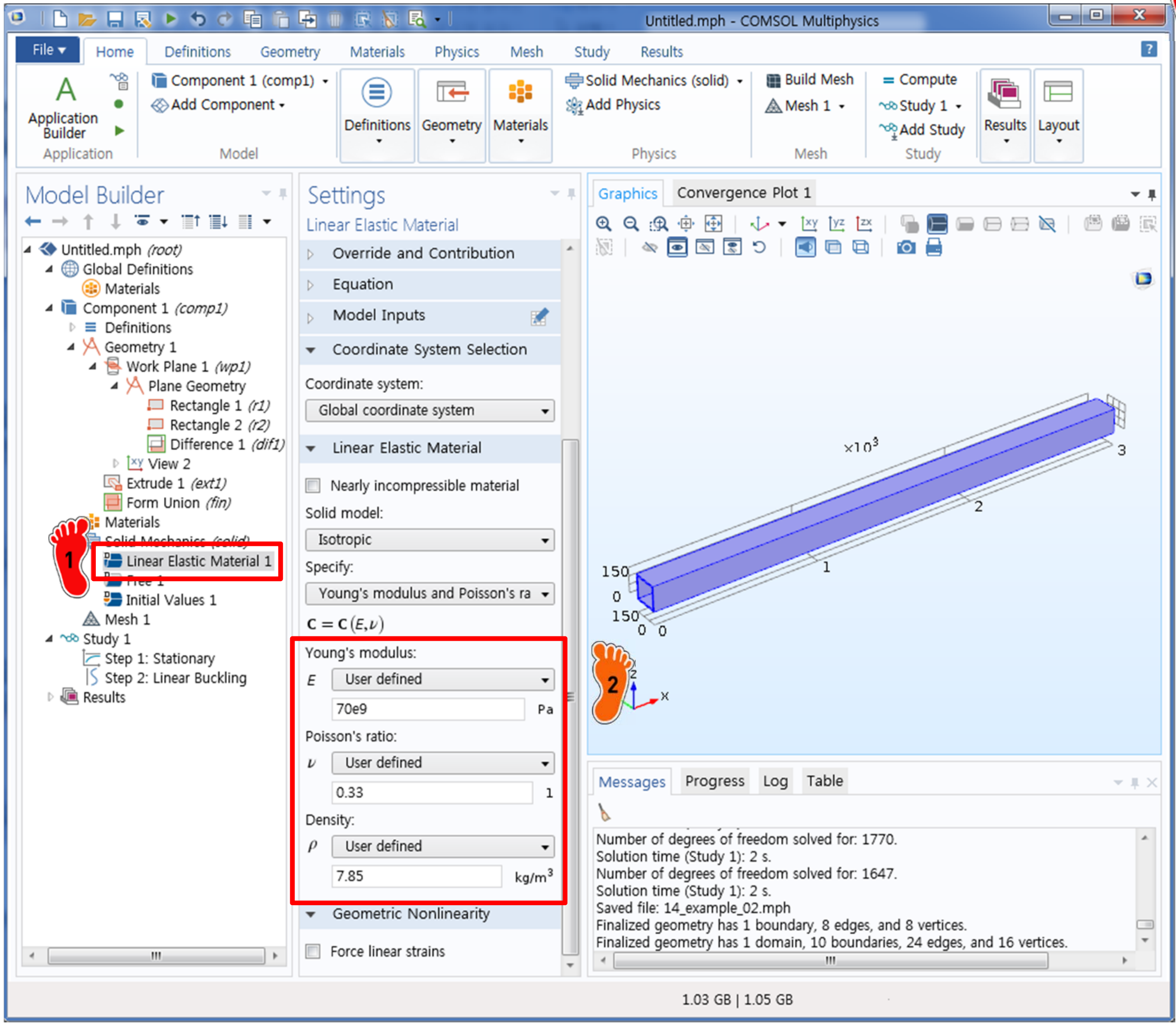
GEOMETRY CREATION



1 Work Plane을 이용하여 단면을 생성하고,

Extrude기능을 사용하여 기하형상 생성

MATERIAL PROPERTY

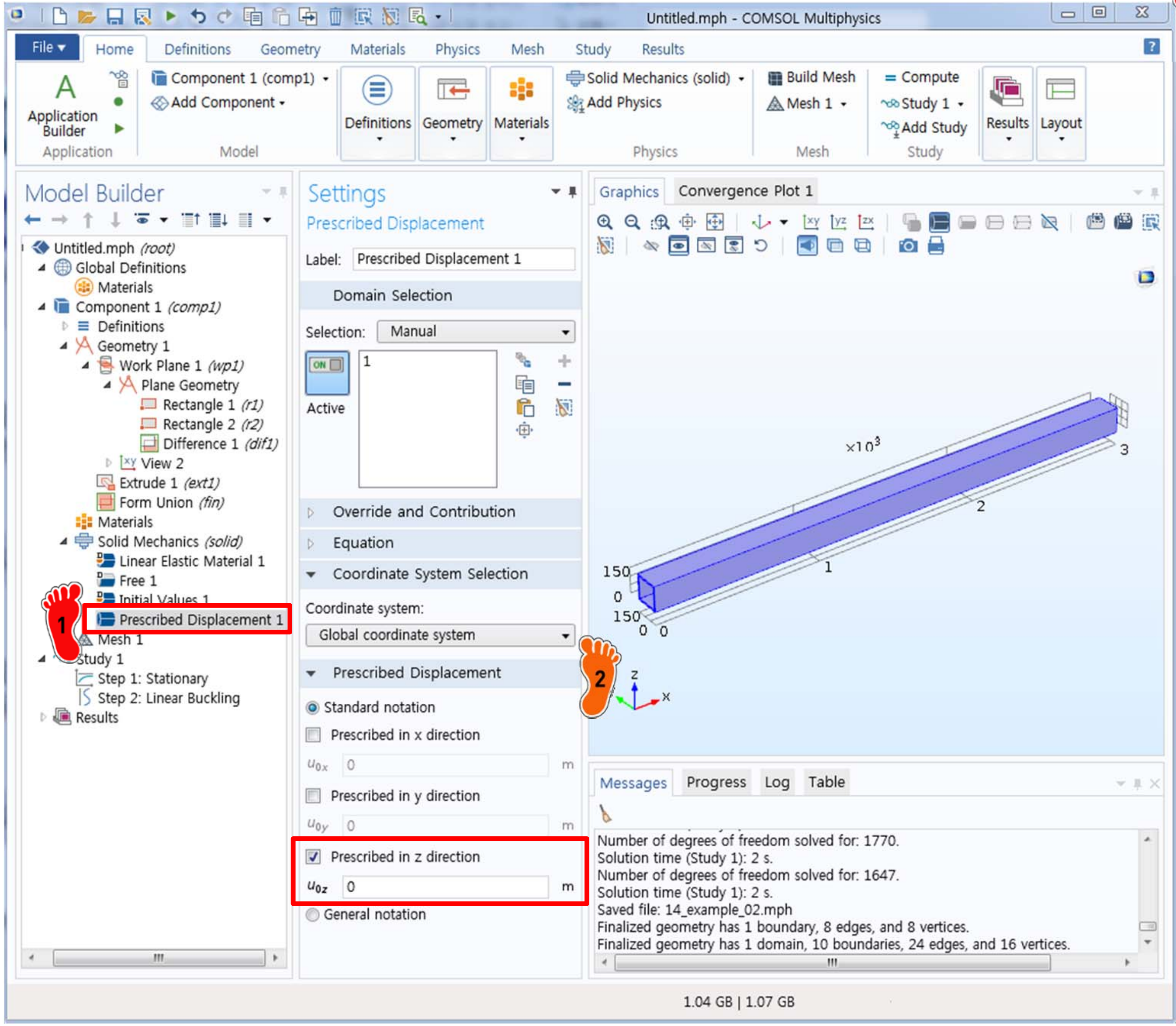


1 Linear Elastic Material 클릭

2 E: 70e9
mu: 0.33
rho : 7.85

입력

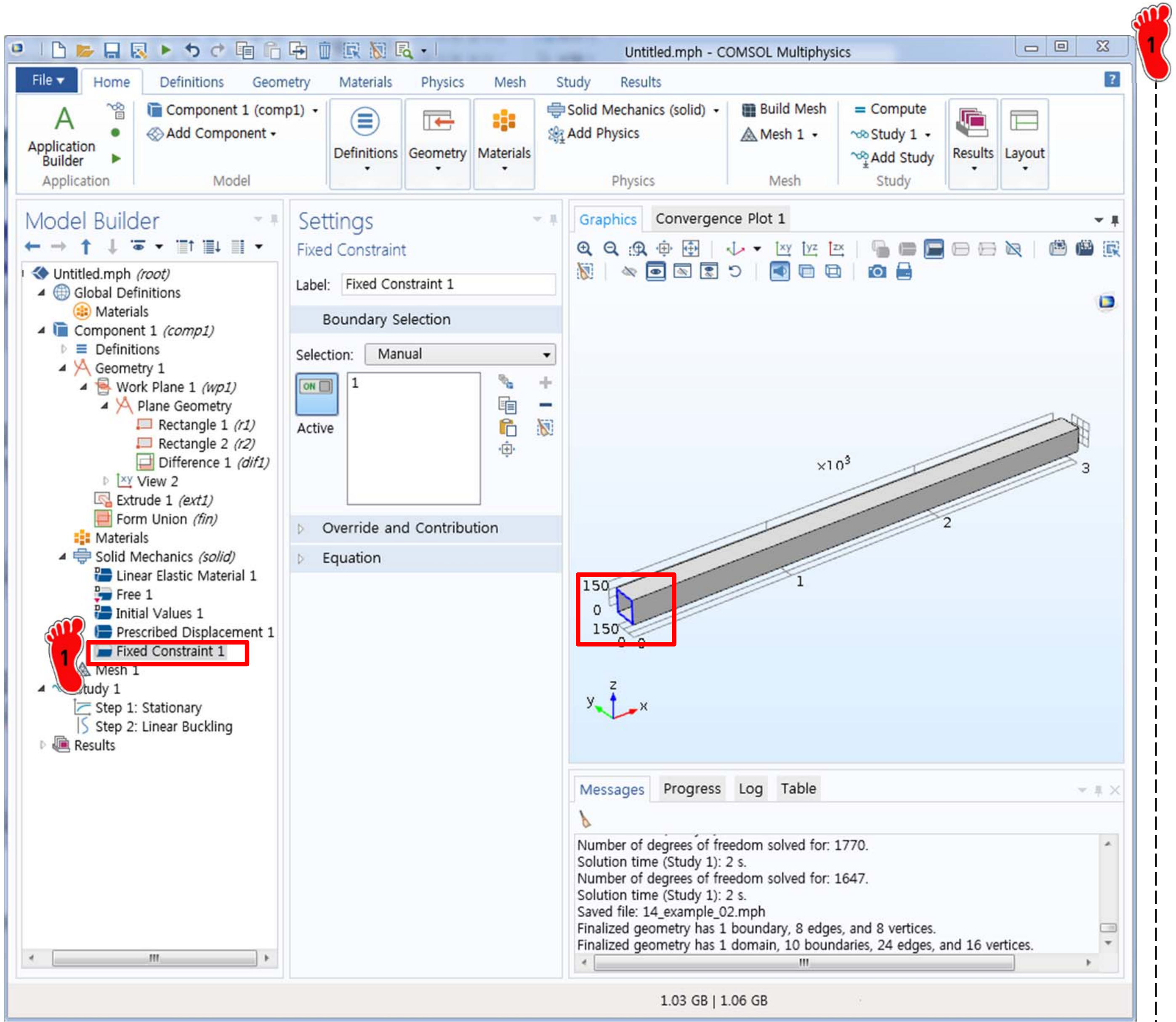
BOUNDARY CONDITION



1 Prescribed Displacement
경계조건 생성

2 솔리드 전체의 z방향 변위
구속

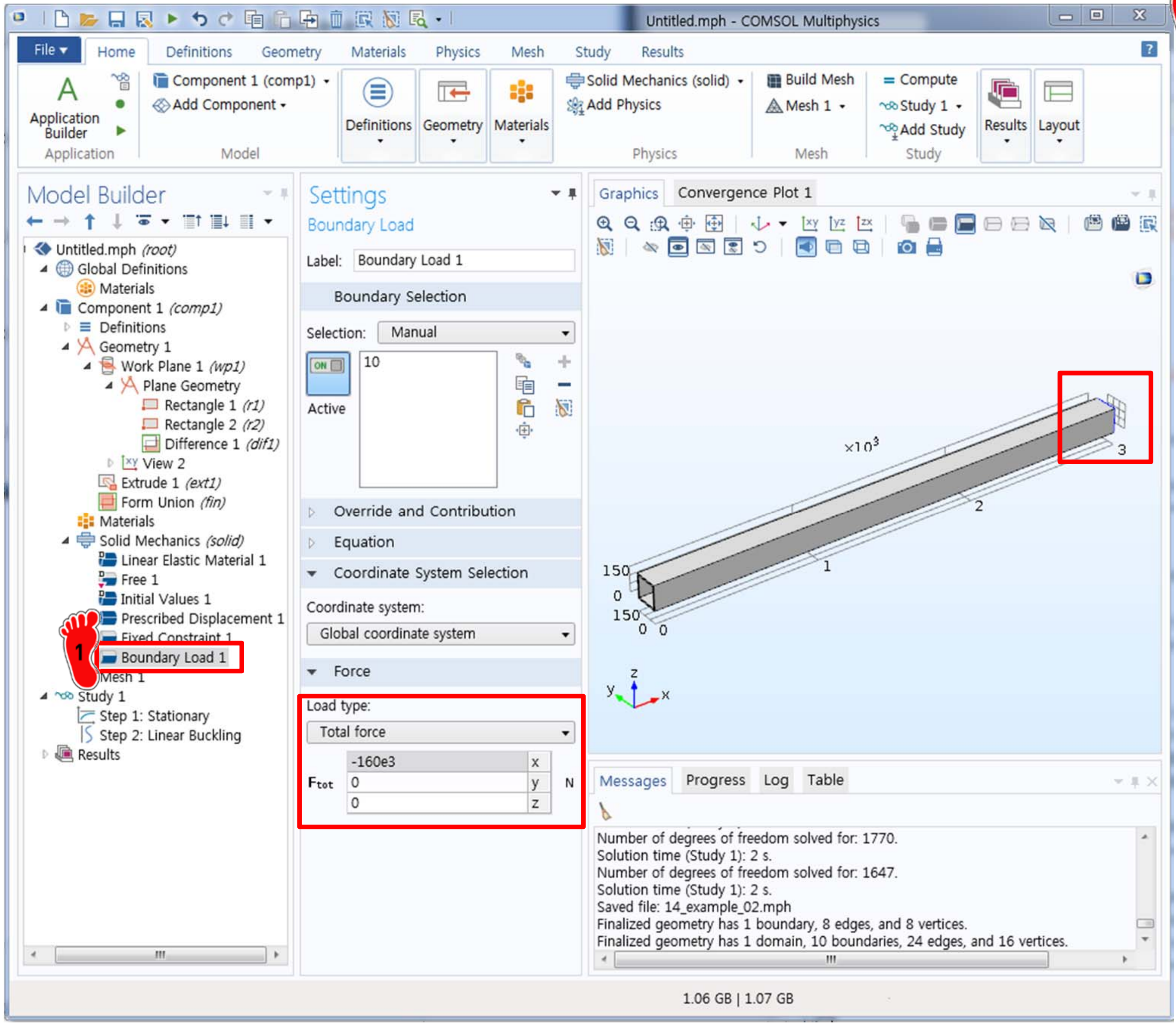
BOUNDARY CONDITION



1 Fixed Constraint 경계조건 생성

한쪽 면 고정구속

BOUNDARY CONDITION

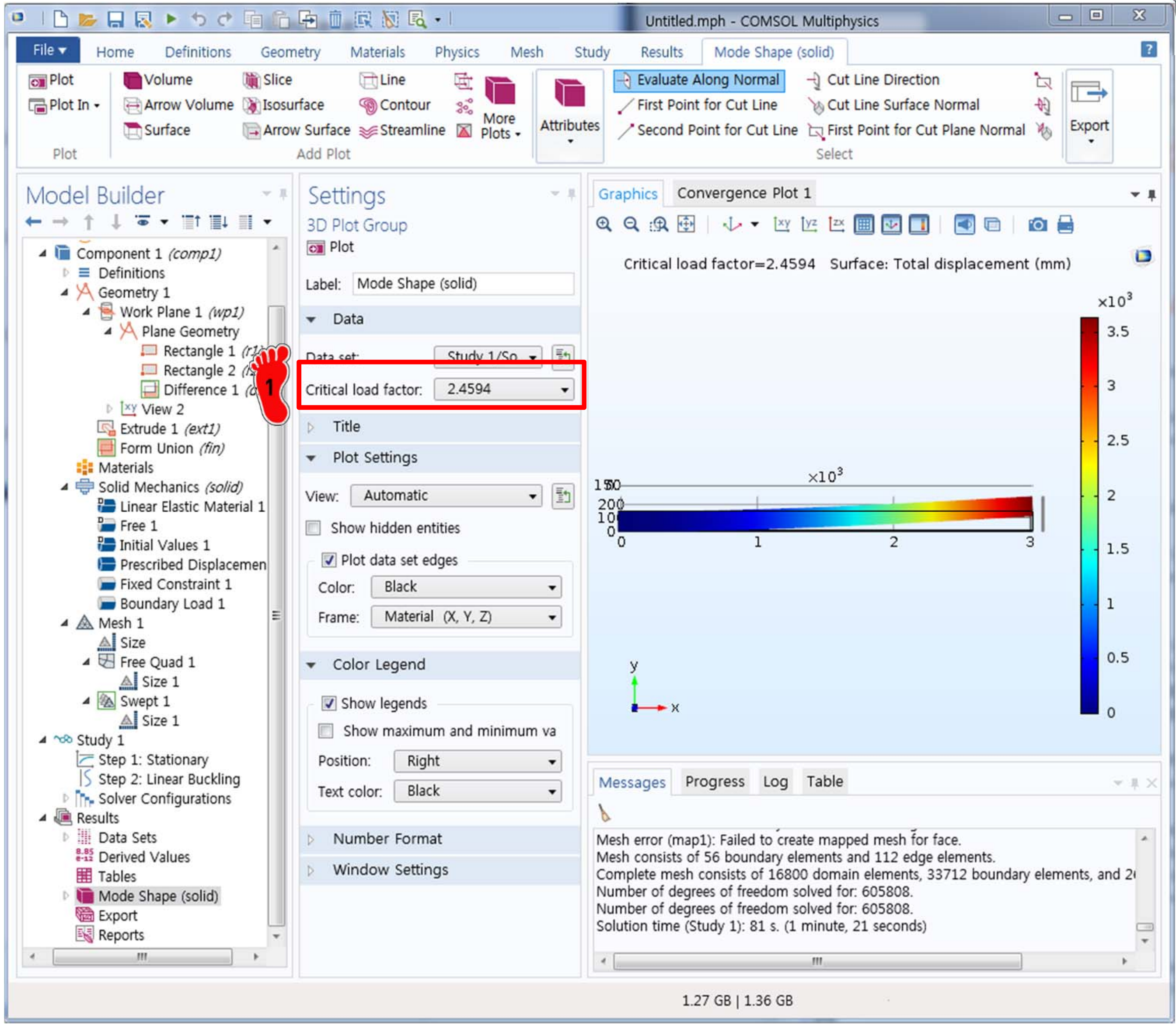


1 Boundary Load 생성

반대쪽 면에 160 kN의 압축력 생성

유한요소 생성 후,
해석 실행

POST-PROCESSING



1 Critical load factor와 좌굴 형상 확인

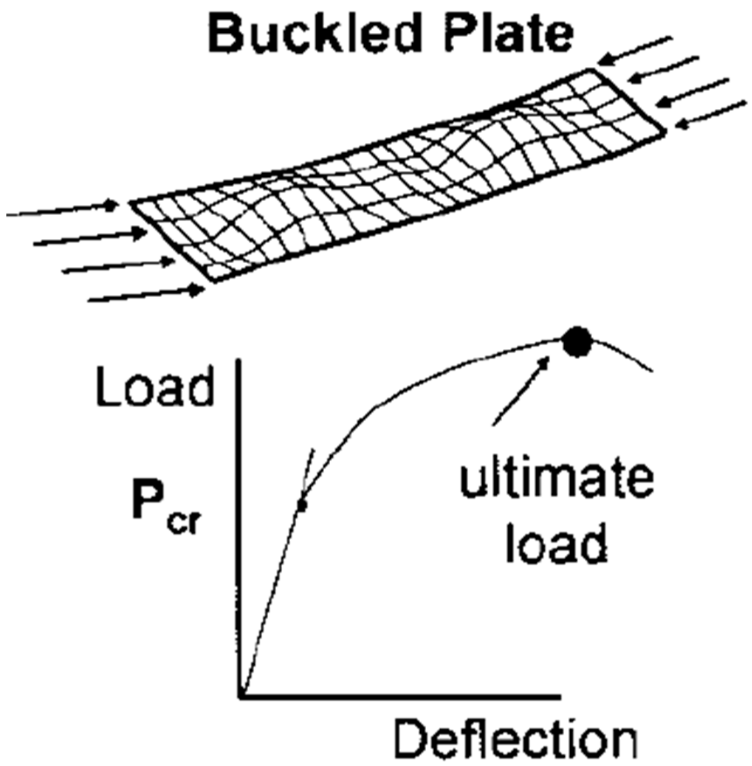
1차 좌굴 하중: 2.46×160kN

$$P_1 = 393.6 \text{ kN}$$

$$P_{1,\text{analytic}} = 352.9 \text{ kN}$$

PANEL BUCKLING (1)

$$\sigma_{cr} = \frac{D\pi^2}{tb^2}k = \frac{E\pi^2}{12\left(1-\nu^2\right)\left(b/t\right)^2}k$$



Case	Boundary Condition	Loading	k
(a)	ss, ss, ss, ss	Compression	4.0
(b)	ss, fixed, fixed, ss	Compression	6.97
(c)	ss, ss, free, ss	Compression	0.425
(d)	ss, fixed, free, ss	Compression	1.277
(e)	ss, fixed, ss, ss	Compression	5.42
(f)	ss, ss, ss, ss	Shear	5.34
(g)	ss, fixed, free, ss	Shear	8.98
(h)	ss, ss, ss, ss	Bending	23.9
(i)	fix, fixed, fixed, fix	Bending	41.8

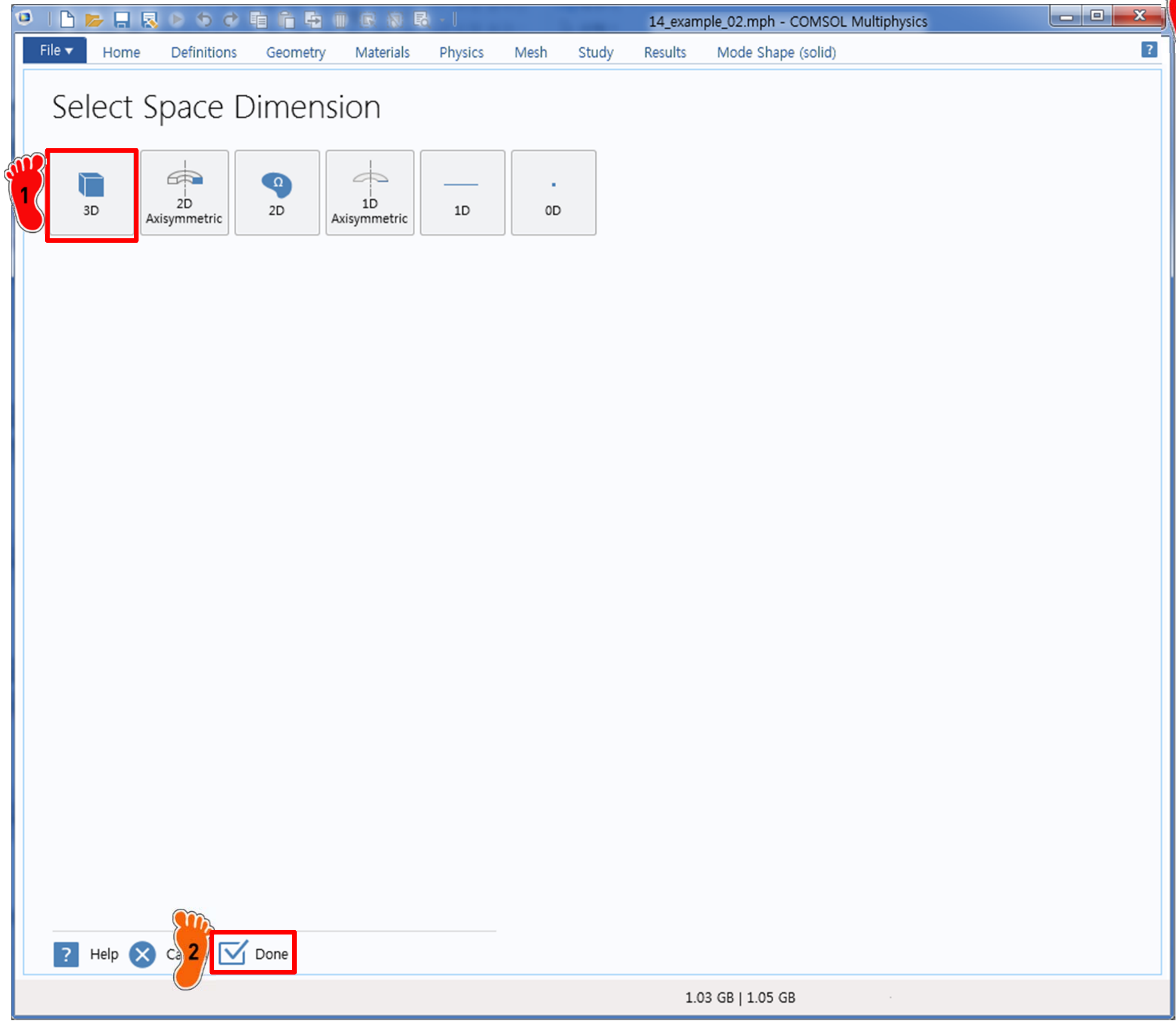
PANEL BUCKLING (2)

$$\sigma_{cr} = \frac{D\pi^2}{tb^2}k = \frac{E\pi^2}{12\left(1-\nu^2\right)\left(b/t\right)^2}k \qquad E = 210\ \text{GPa}, \nu = 0.28, b = 20\ \text{mm}, t = 1\ \text{mm}$$

Case	Boundary Condition	Loading	k
(a)	ss ss ss ss	Compression	4.0
(b)	fixed ss ss fixed	Compression	6.97
(c)	ss ss ss free	Compression	0.425
(d)	fixed ss ss free	Compression	1.277
(e)	fixed ss ss ss	Compression	5.42
(f)	ss ss ss ss	Shear	5.34
(g)	fixed ss ss free	Shear	8.98
(h)	ss ss ss ss	Bending	23.9
(i)	fixed fix fix fixed	Bending	41.8

$$\sigma_{cr} = 1874\ \text{MPa},\ P_{cr} = \sigma_{cr}A = \sigma_{cr}bt = 37482N$$

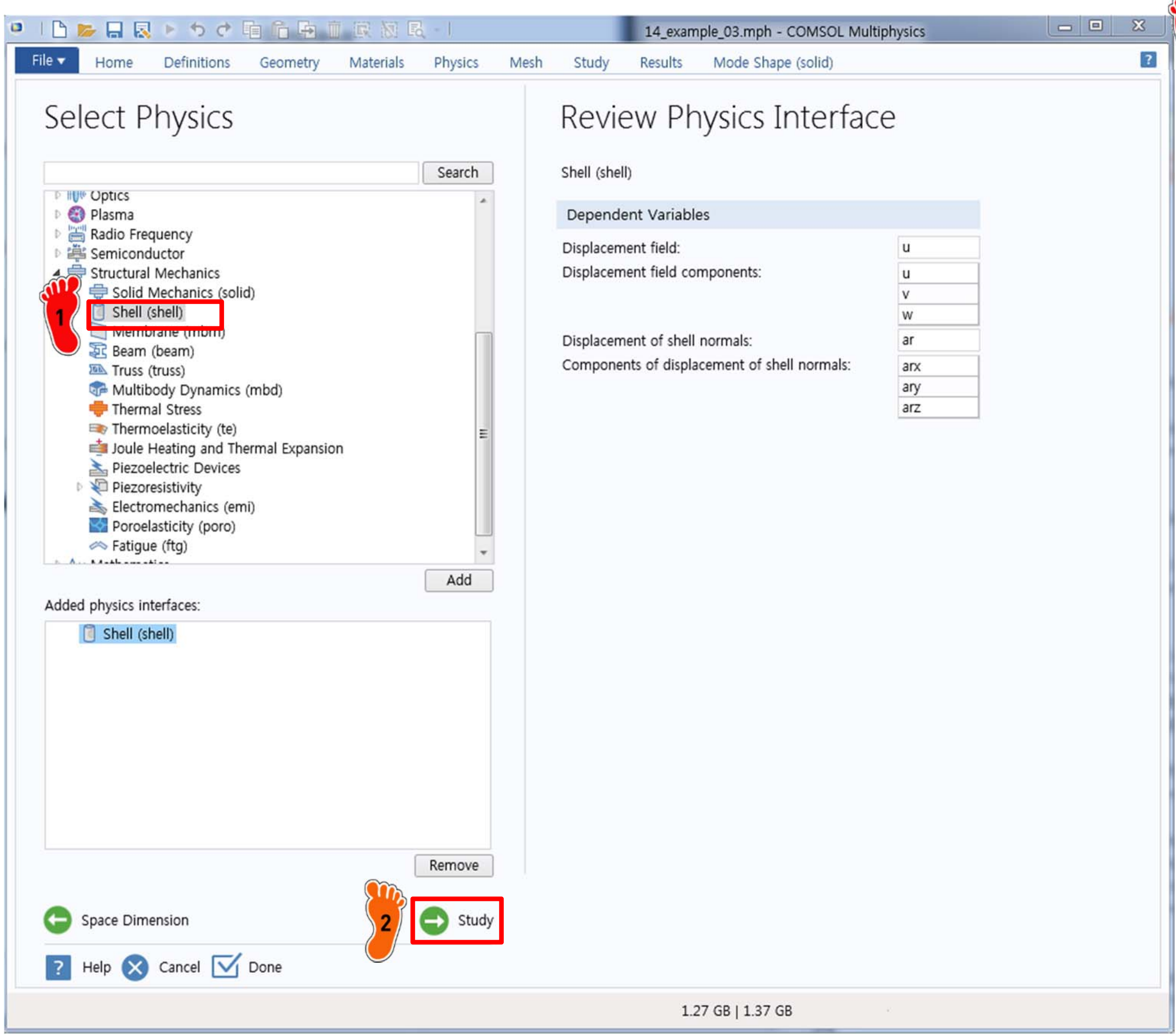
DIMENSION SELECTION



1 3D 선택

2 Done 클릭

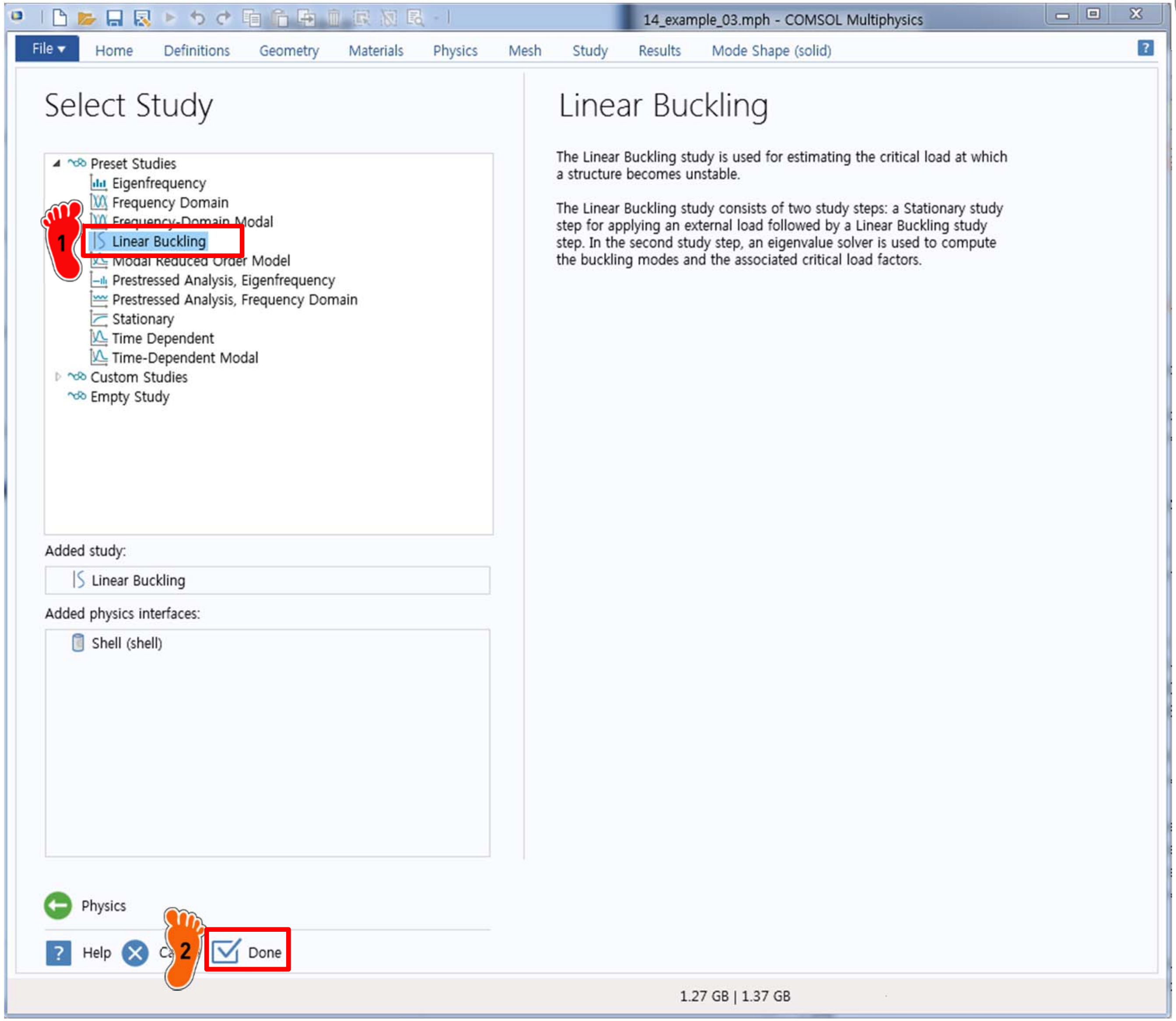
PHYSICS SELECTION



1 Structural Mechanics 의 Shell 선택

2 Study 클릭

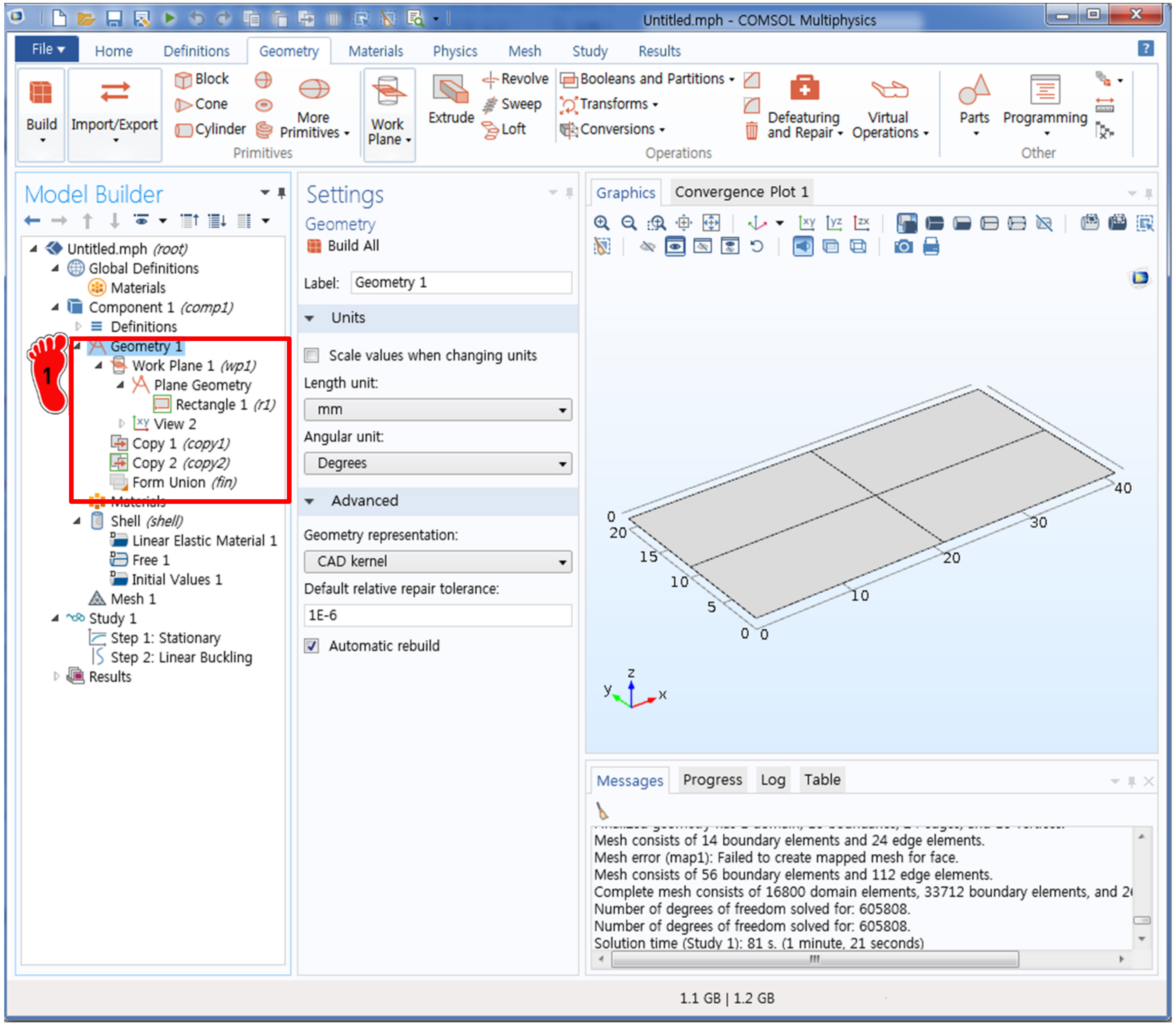
STUDY TYPE SELECTION



1 Linear Buckling선택

2 Done 클릭

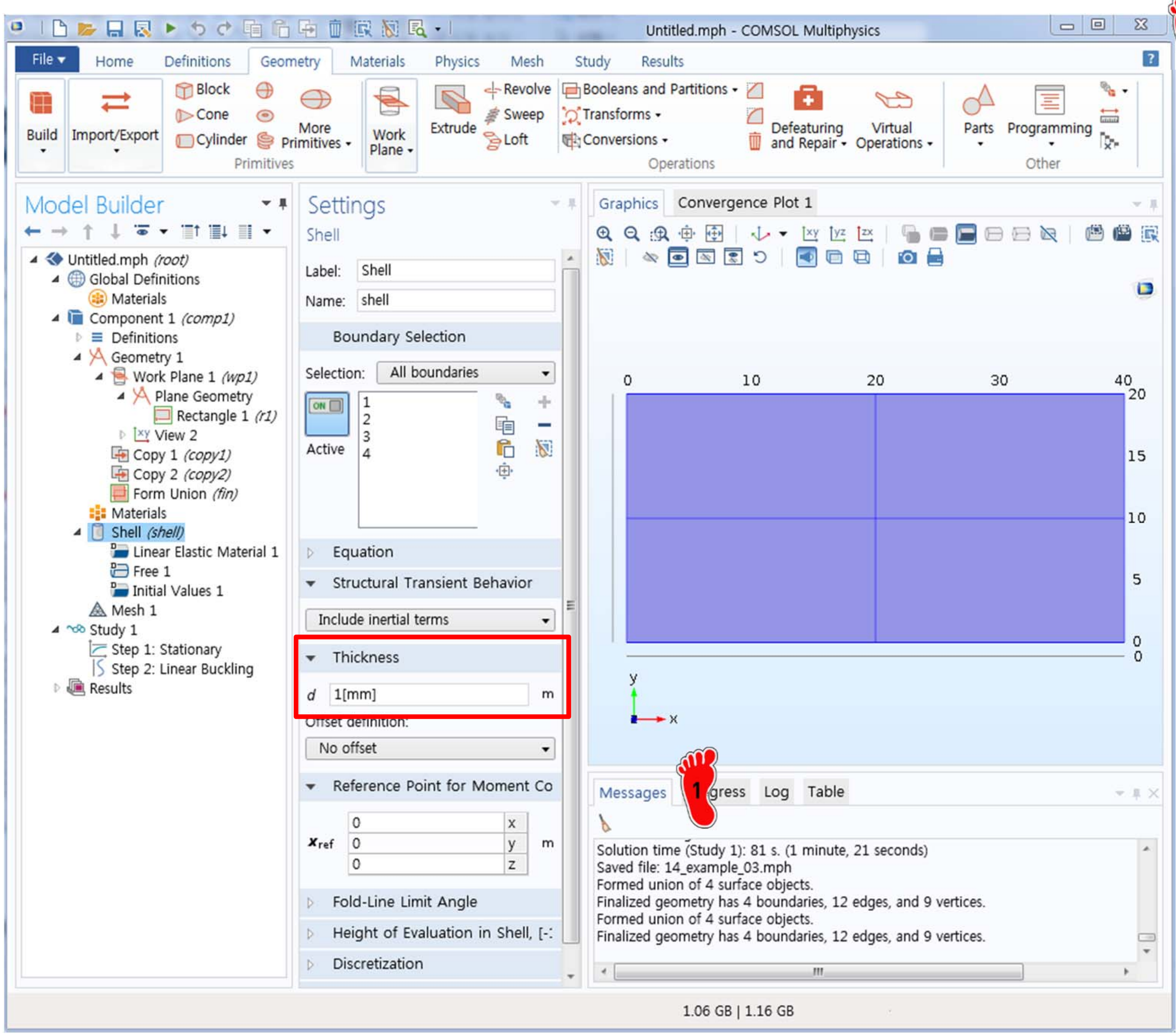
GEOMETRY CREATION



1 경계조건을 설정할 수 있도록, 4개의 분할된 기하형상 생성

Work Plane, Rectangle, Copy 기능 사용

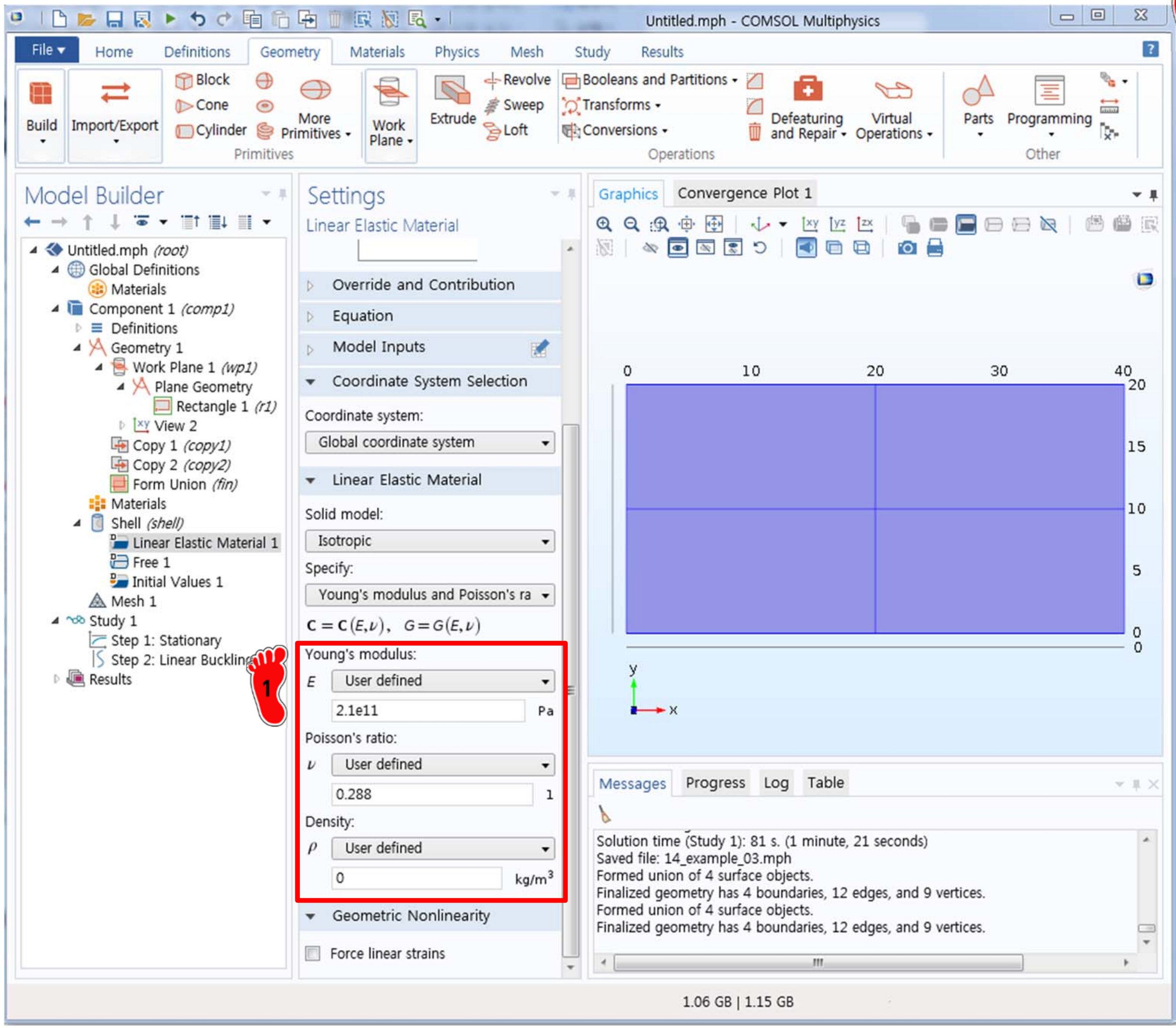
THICKNESS



1 Shell클릭

Thickness : 1 [mm]

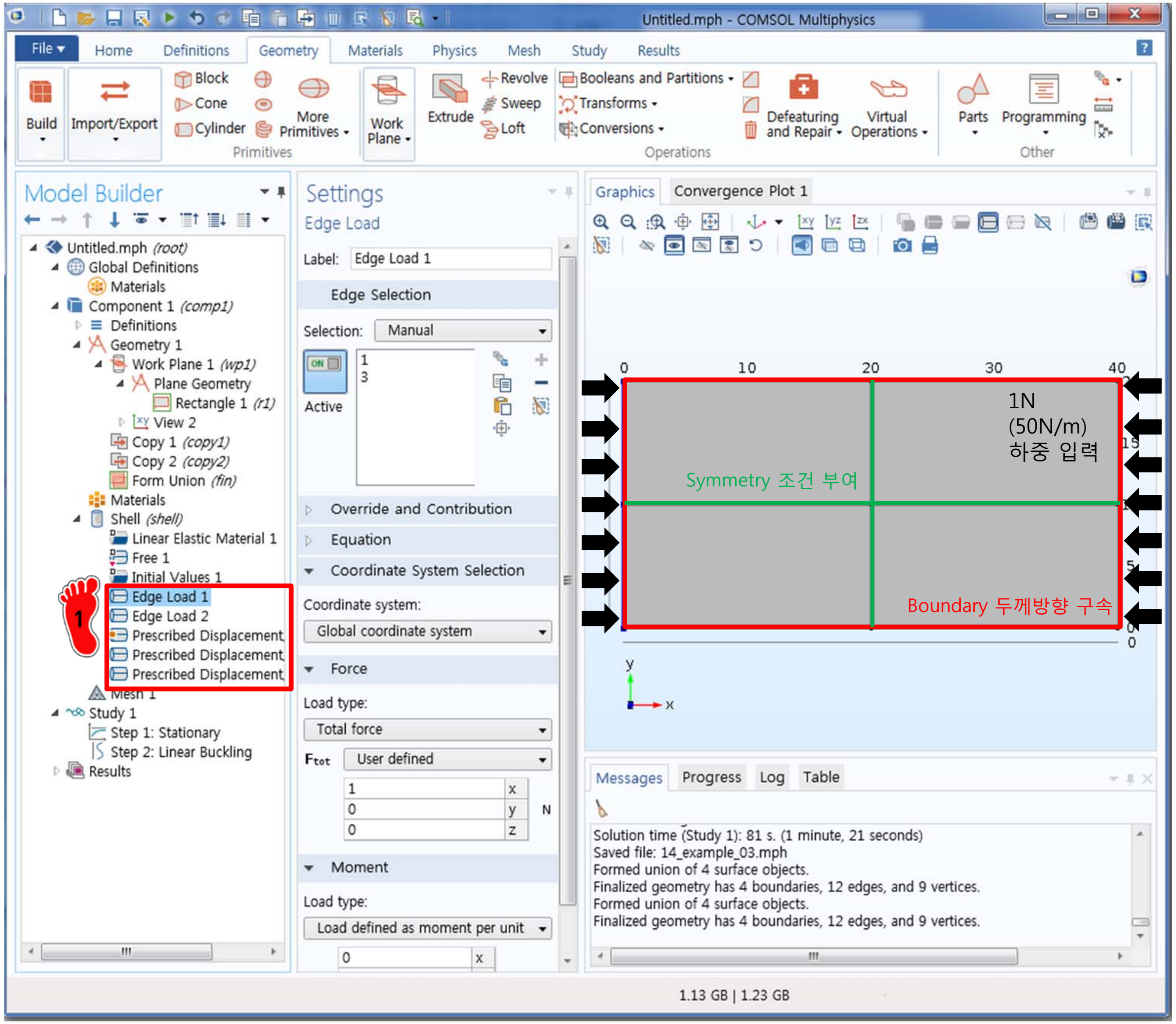
MATERIAL PROPERTIES



1 Linear Elastic Material 클릭

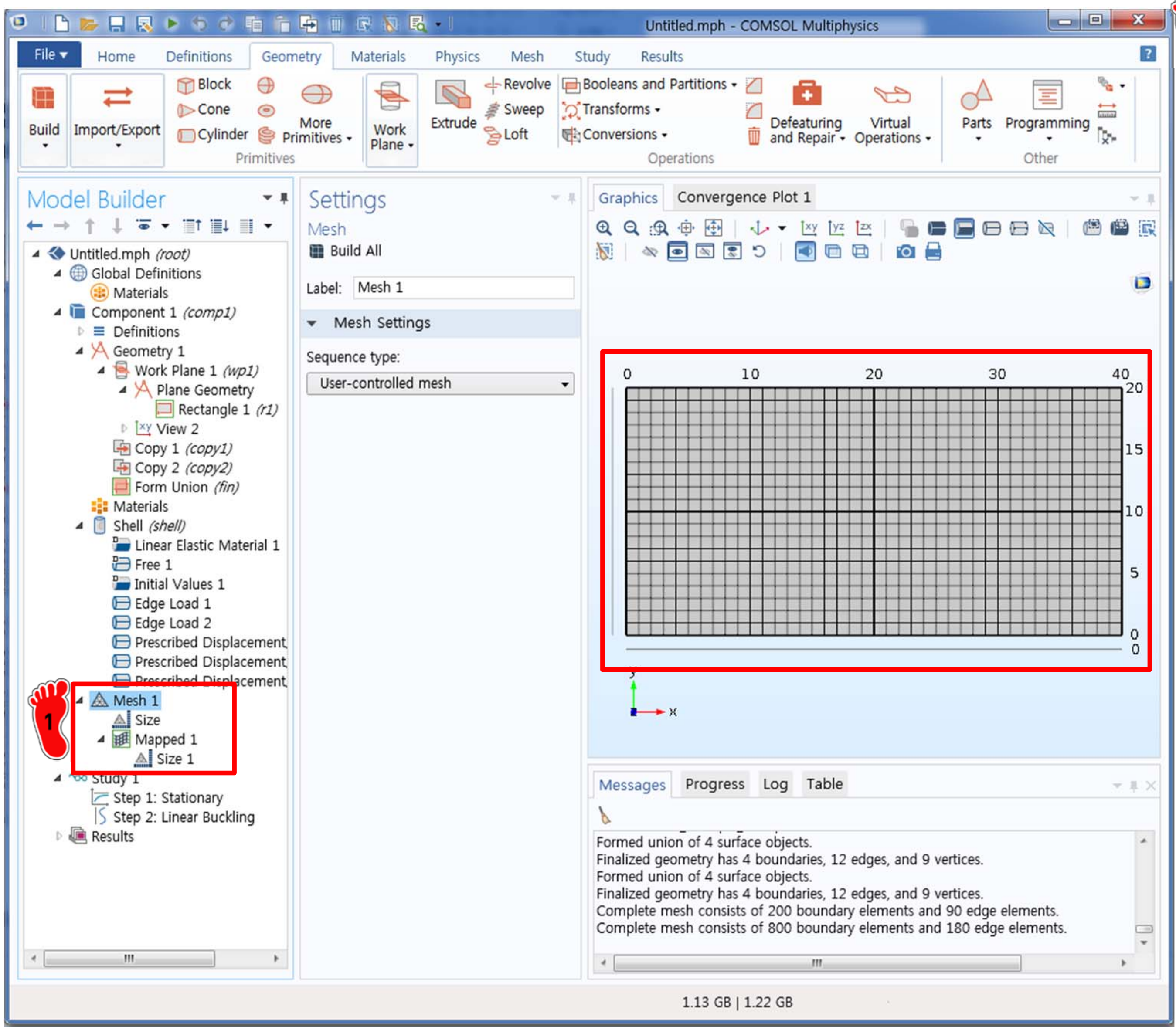
E: 2.1e11
mu: 0.28
rho : 0

BOUNDARY CONDITIONS



1 하중 및 경계조건 입력

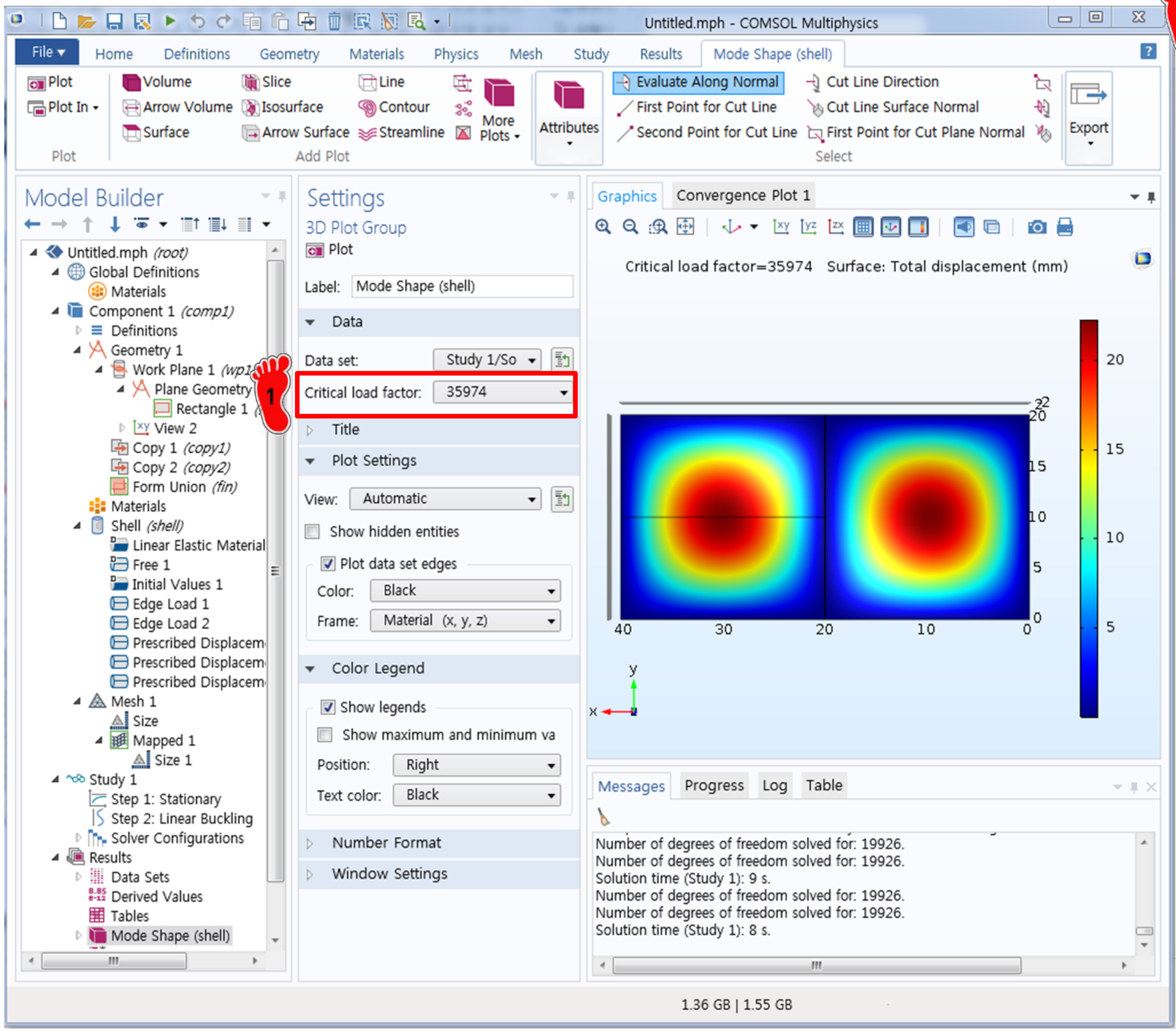
MESH



1 Mesh 생성 후,

해석 실행

POST-PROCESSING



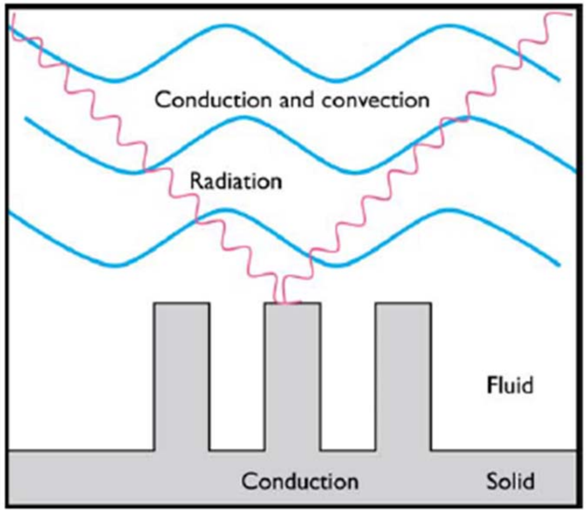
1 첫 번째 고유값은 3.597e4
임계 하중은 고유값 곱하기
가해준 하중이므로
3.597e4이 임계하중

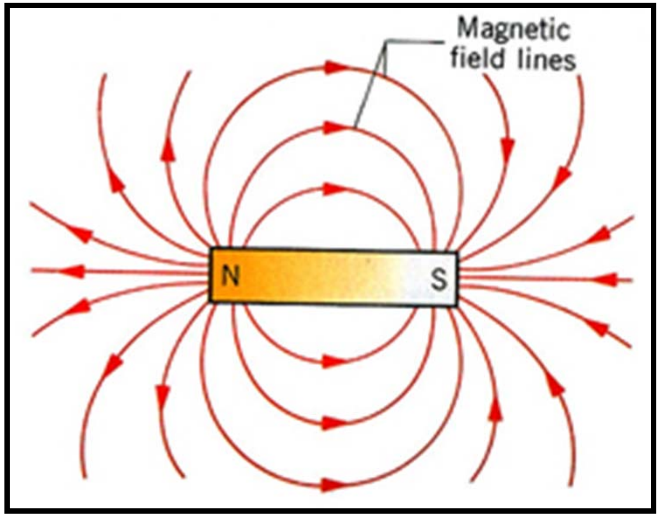
Analytic solution

$$\sigma_{cr} = 1874 \text{ MPa}$$

$$P_{cr} = \sigma_{cr} A = 37482 N$$

Heat Transfer / Electromagnetics





Computational Design Laboratory
Department of Automotive Engineering
Hanyang University, Seoul, Korea

한양대학교 HANYANG UNIVERSITY
CDL Computational Design Lab

CONTENTS

- **Heat Transfer**
  - ✓ **2D/3D model**
  - ✓ **Weak Formulation**
- **Electromagnetics**
  - ✓ **Resistance calculation**
  - ✓ **C-core Actuator**
- **Assignment**

HEAT TRANSFER

  - movement of energy due to a temperature difference
- Conduction
  - heat transfer by diffusion in a stationary medium due to a temperature gradient. The medium can be a solid or a liquid.
- Convection
  - heat transfer between either a hot surface and a cold moving fluid or a cold surface and a hot moving fluid. Convection occurs in liquids and gases.
- Radiation
  - heat transfer between Surface A at temperature T_1 and Surface B at temperature T_2 via electromagnetic waves, provided that $T_1 \neq T_2$ and that Surface A is visible to an infinitesimally small observer on Surface B.

HEAT CONDUCTION

- Governing Equation

$$\rho C \frac{\partial T}{\partial t} - \nabla \cdot \left(k \nabla T \right) = Q$$

$$k \nabla^2 T + Q = 0$$

T : temperature
ρ : density
C : heat capacity
k : thermal conductivity
Q: heat source or heat sink

- Boundary Conditions

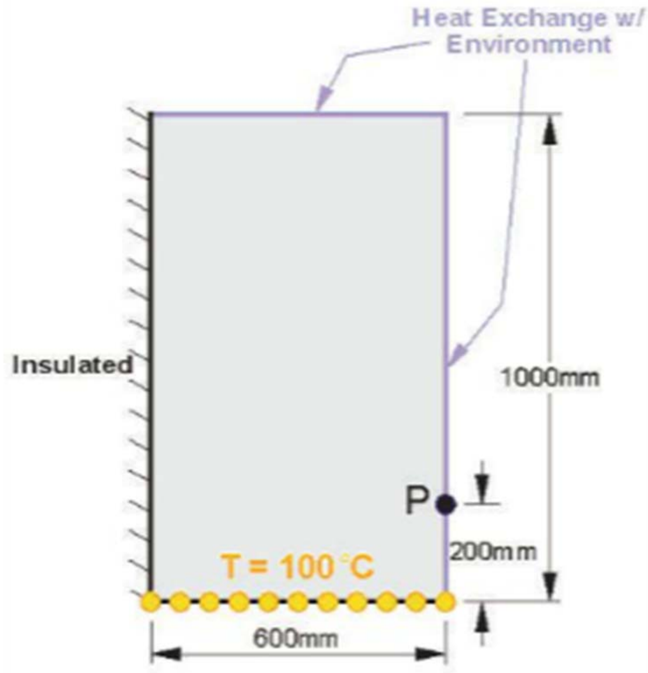
BOUNDARY CONDITION	DESCRIPTION
$\mathbf{n} \cdot (k \nabla T) = q_0 + h(T_{inf} - T) + C_{const}(T_{amb}^4 - T^4)$	Heat flux
$\mathbf{n} \cdot (k \nabla T) = 0$	Insulation or symmetry
$T = T_0$	Prescribed temperature
$T = 0$	Zero temperature

CONTENTS

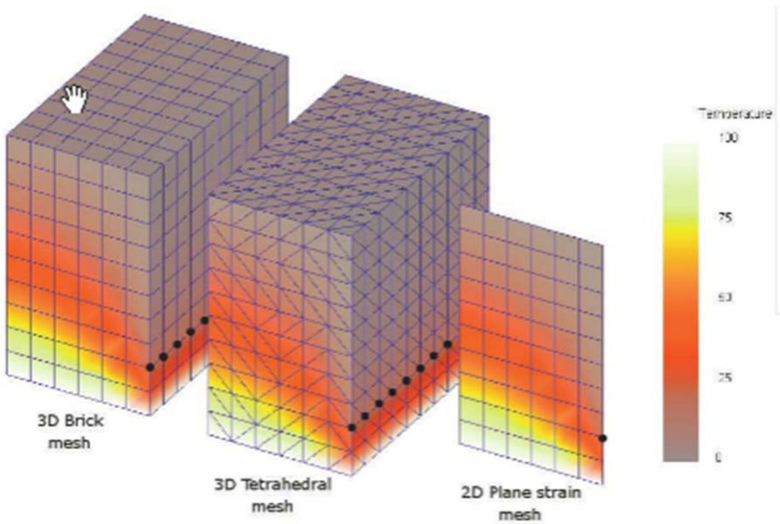
- Heat Transfer
  - ✓ 2D/3D model
  - ✓ Weak Formulation
- Electromagnetics
  - ✓ Resistance calculation
  - ✓ C-core Actuator
- Assignment

NAFEMS T4

- Problem description
  - This analysis studies the behavior of a two-dimensional model as well as its three-dimensional counterpart, under thermal loading. The bottom of the object is held at a constant temperature of 100°C while the top and right edges are allowed to exchange heat with the 0°C environment. This steady-state temperature of point P is the solution of interest.

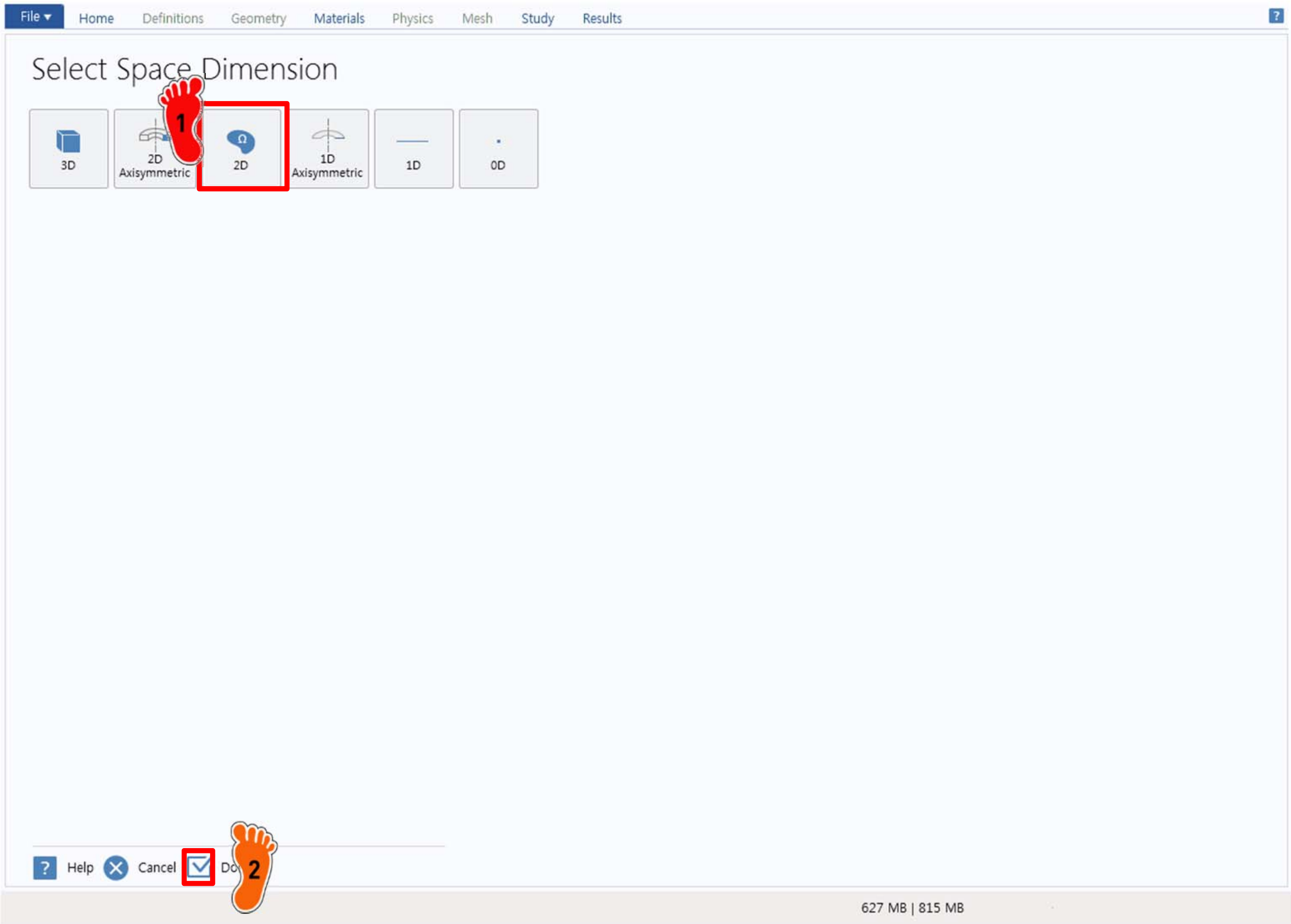


- Element tested
  - 2D / 3D brick / 3D tetrahedral
- Material data
  - Conductivity = 52 W/m°C
  - Convection coefficient = 750 W/(m^2°C)
- Theoretical solution
  - temperature at point P is 18.30°C



		Temperature	% Difference
Theoretical Solution		18.30°C	
2D Plane strain	60 elements	17.95°C	-1.9%
	240 elements	18.09°C	-1.1%
	960 elements	18.21°C	-.5%
	3840 elements	18.24°C	-.3%
3D Bricks	600 elements	18.91°C	3.3%
	2400 elements	18.42°C	.6%
3D Tetrahedrals	2854 elements	18.27 – 19.22°C	
		T_{avg} = 18.86°C	3.1%
	7943 elements	18.30 – 18.88°C	
		T_{avg} = 18.71°C	2.2%

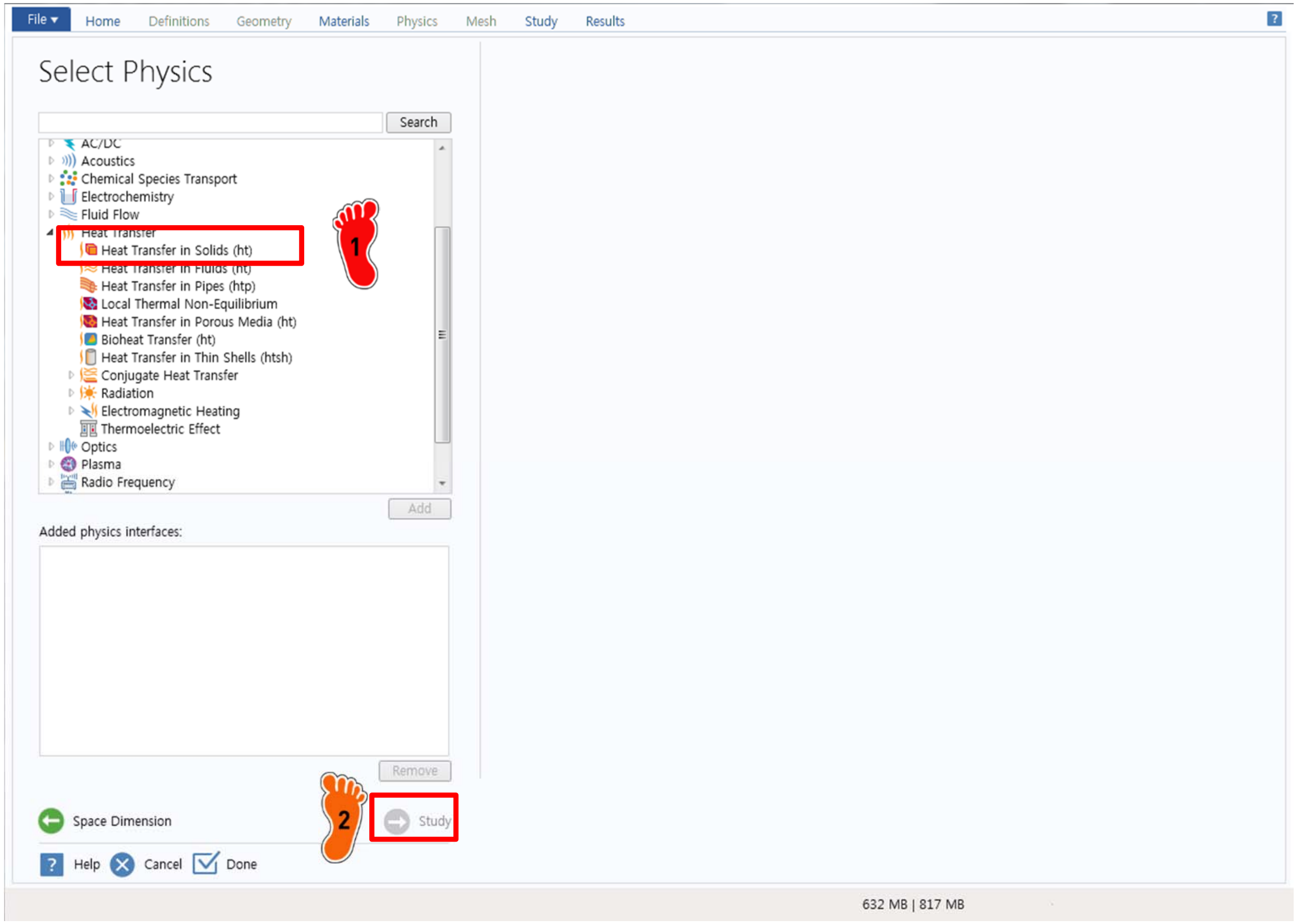
DIMENSION SELECTION



1 2D 선택

2 Done 클릭

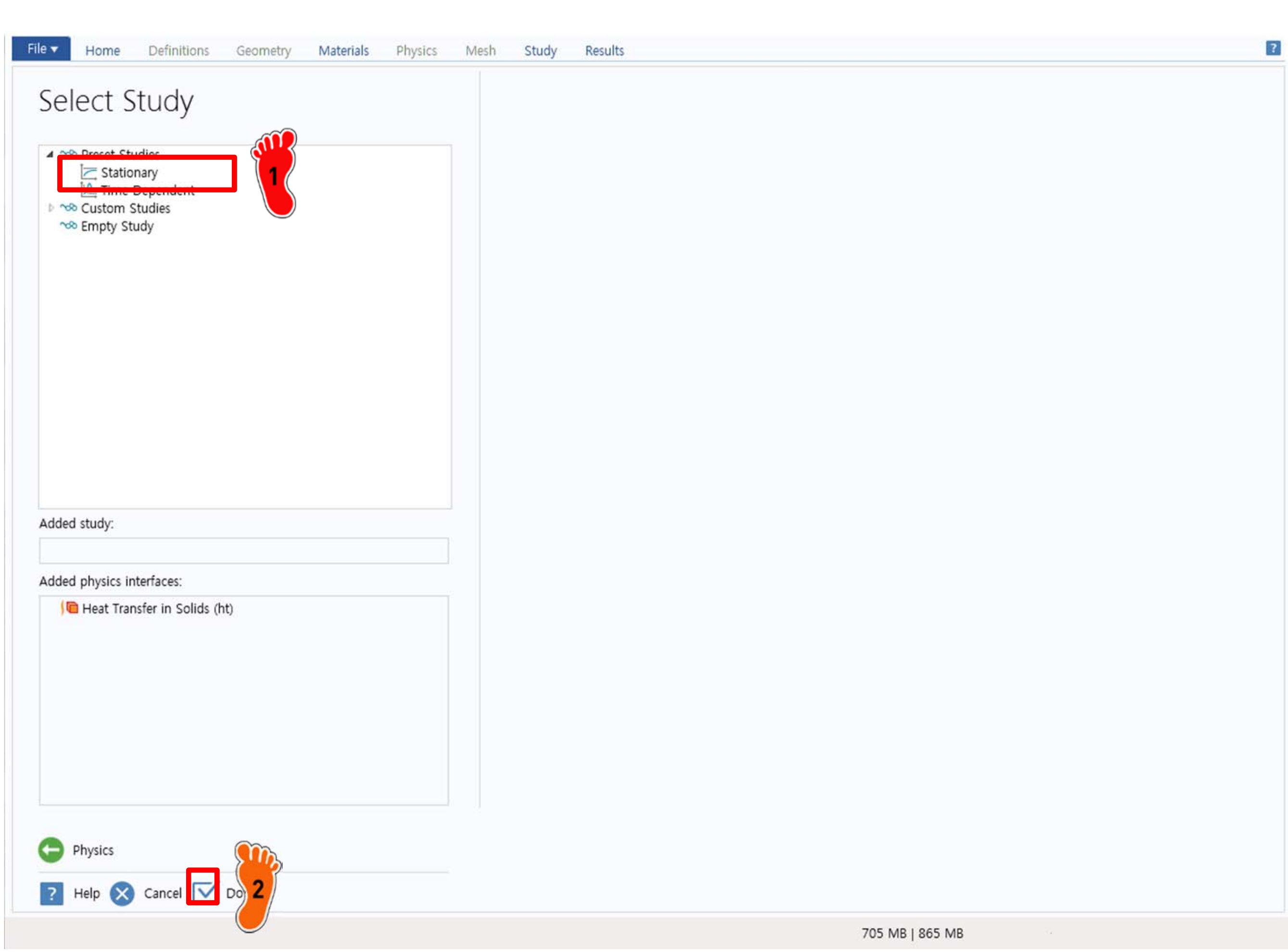
PHYSICS SELECTION



1 Heat Transfer 의 Heat Transfer in Solids선택

2 Study 클릭

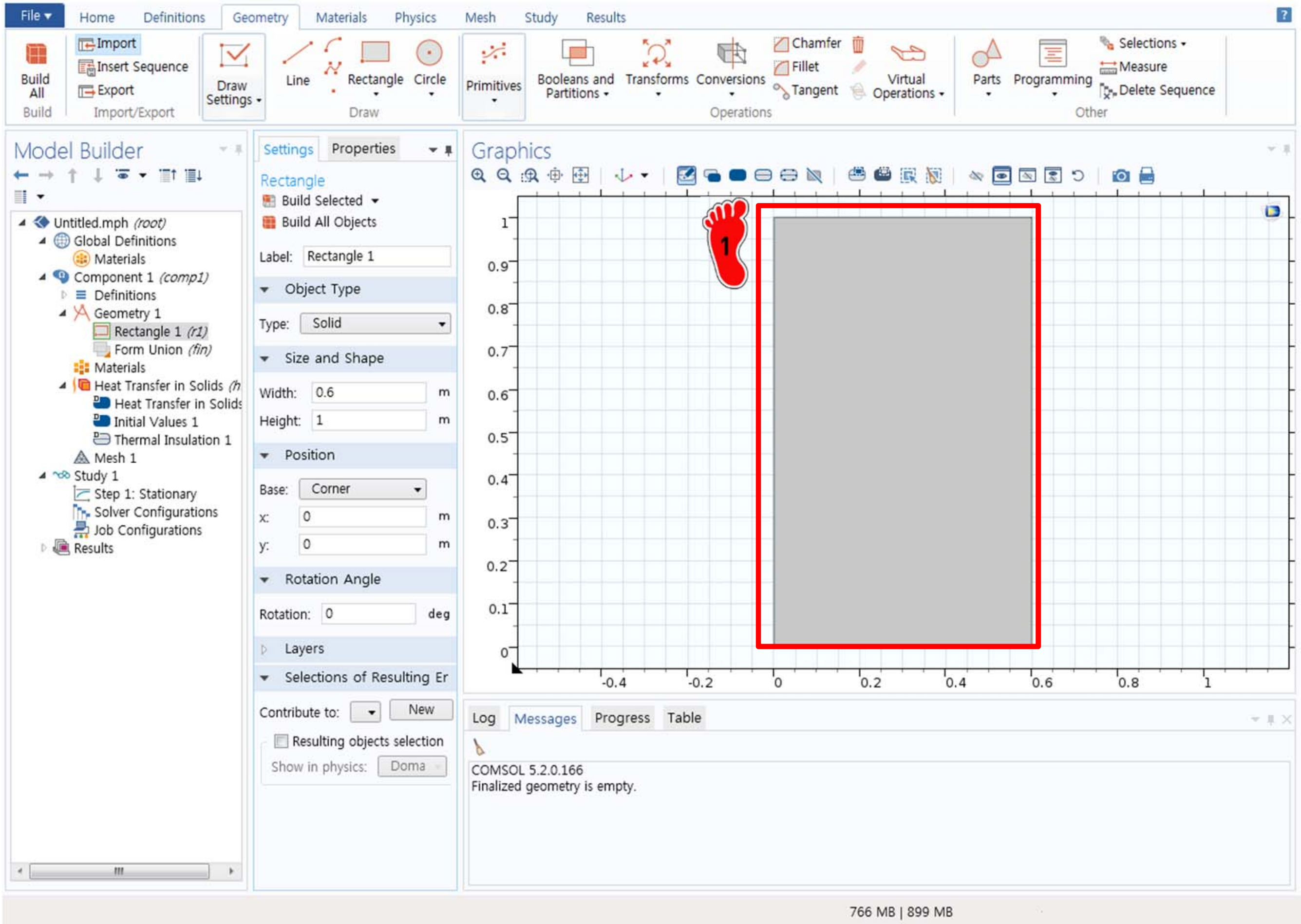
STUDY TYPE SELECTION



1 Stationary 선택

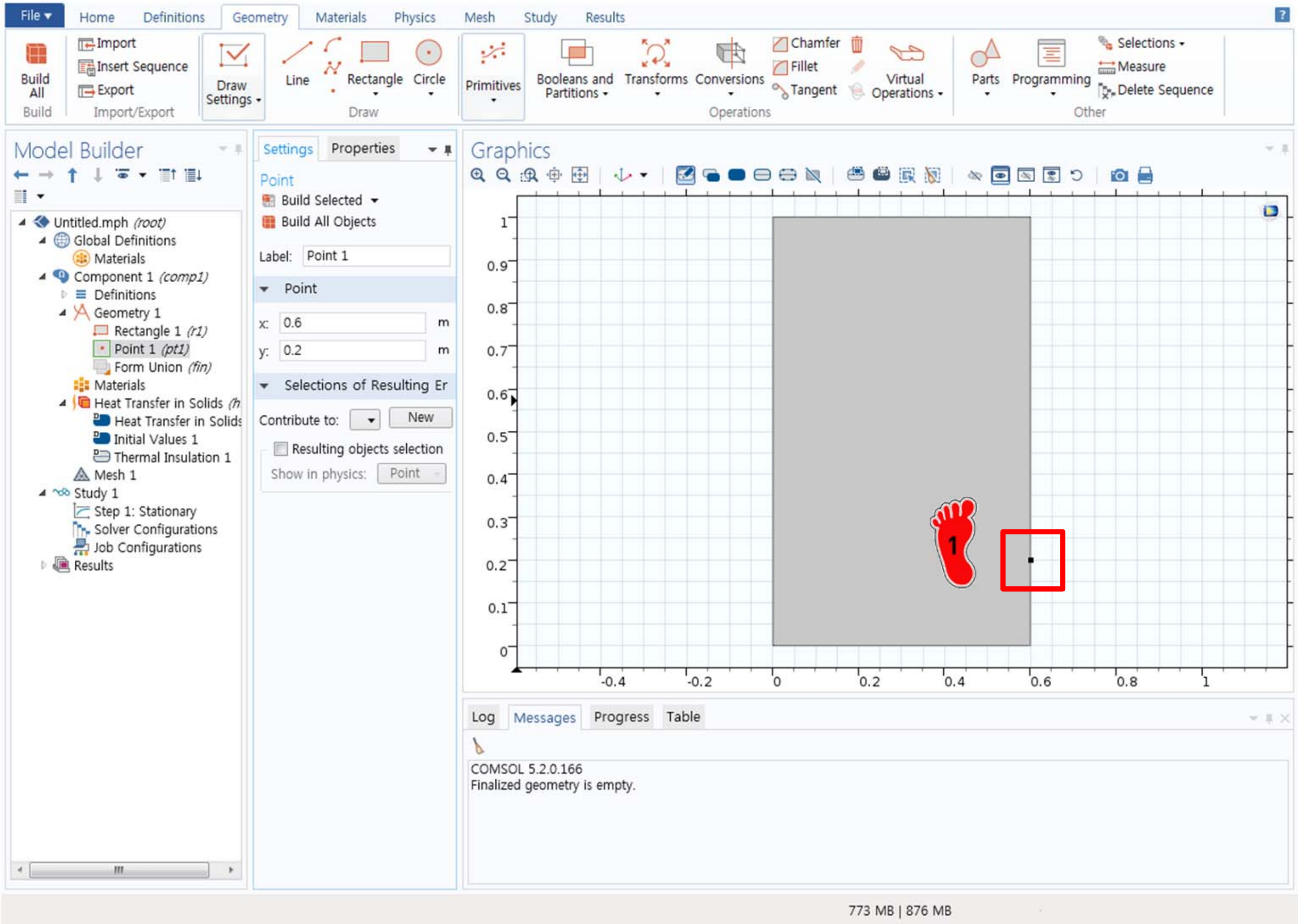
2 Done클릭

GEOMETRY CREATION



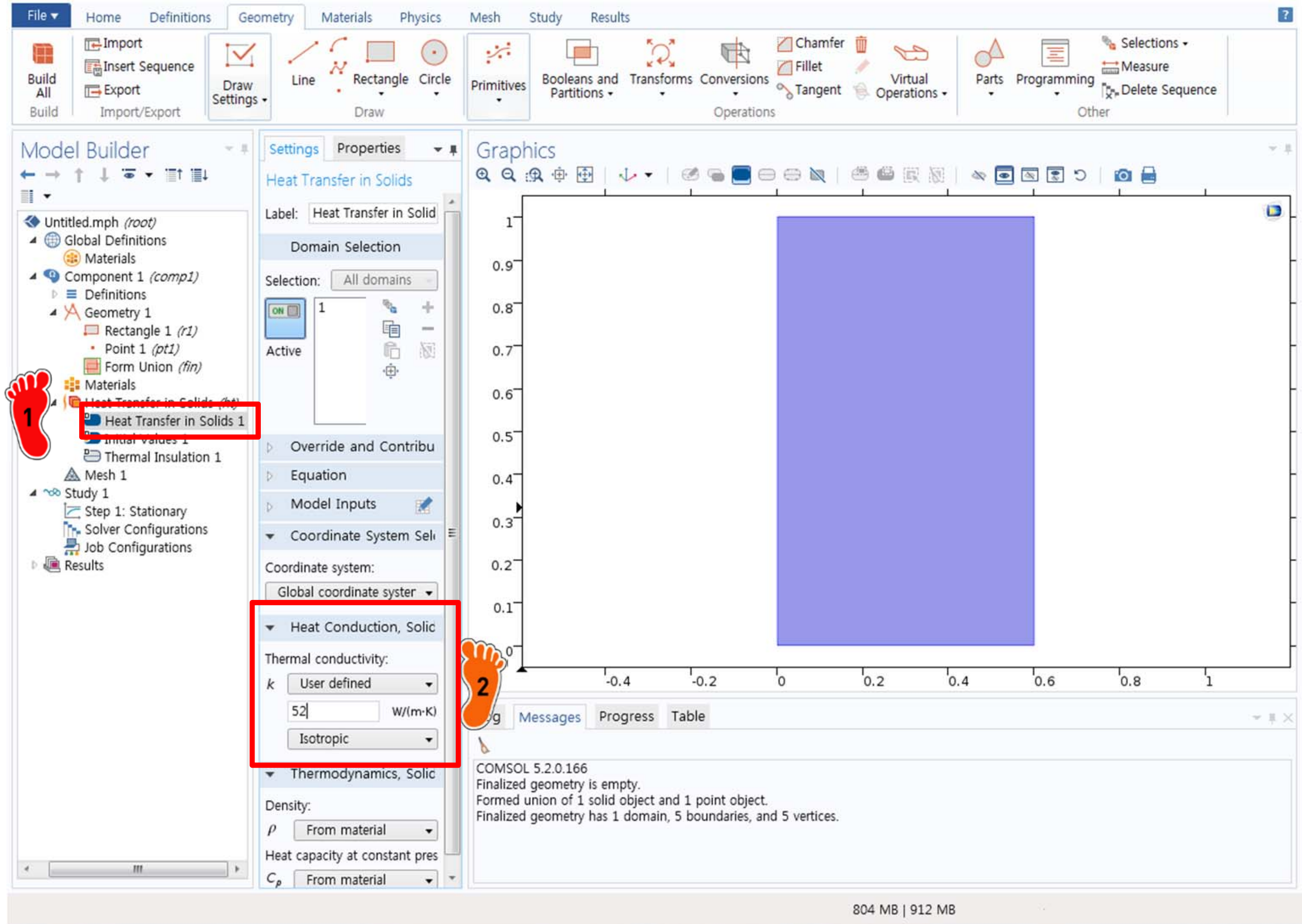
1 가로 600 mm 세로 1000 mm 직사각형 생성

GEOMETRY CREATION



1 (0.6,0.2) 위치에 절점 생성

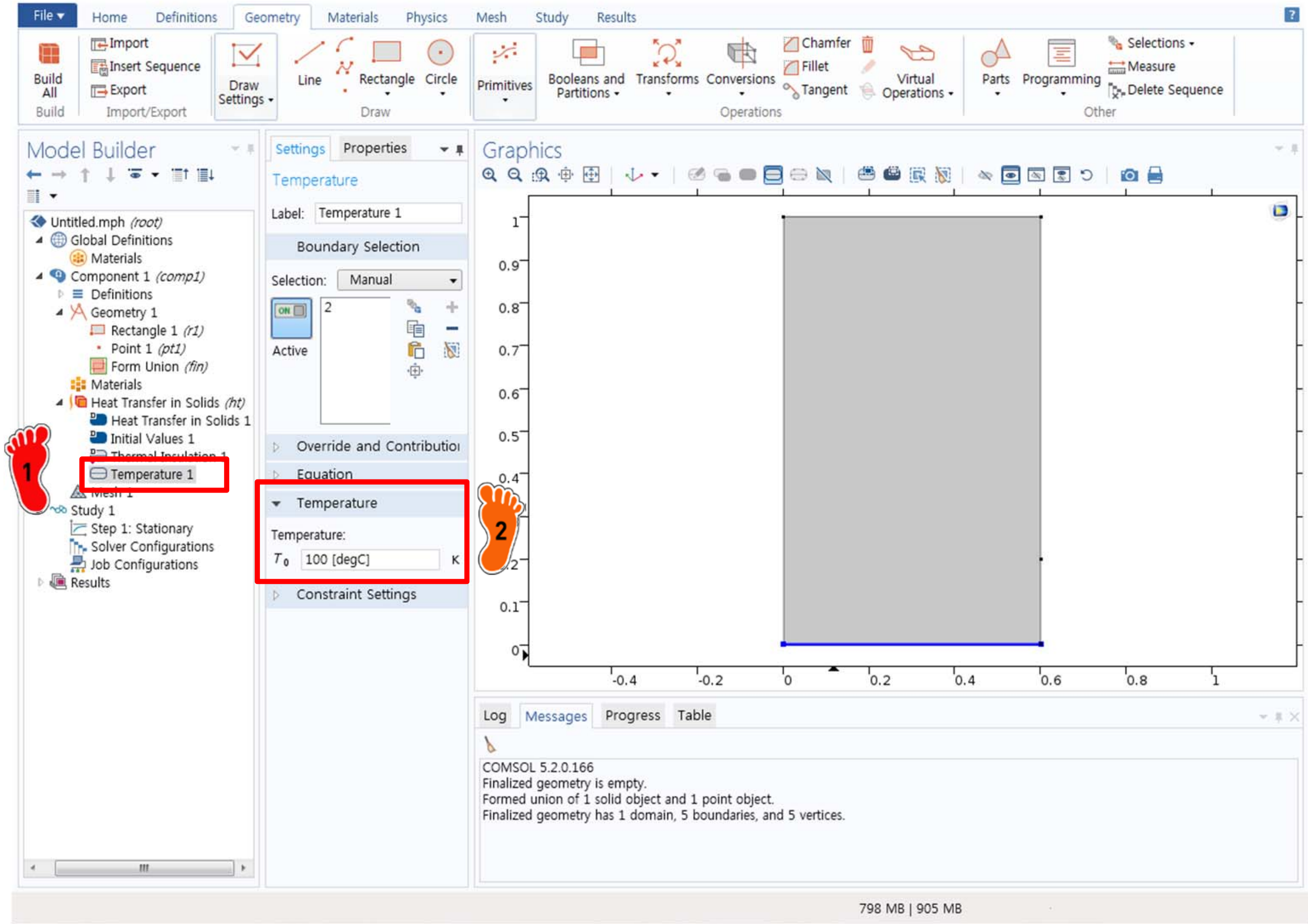
MATERIAL PROPERTY



1 Heat Transfer in Solids 클릭

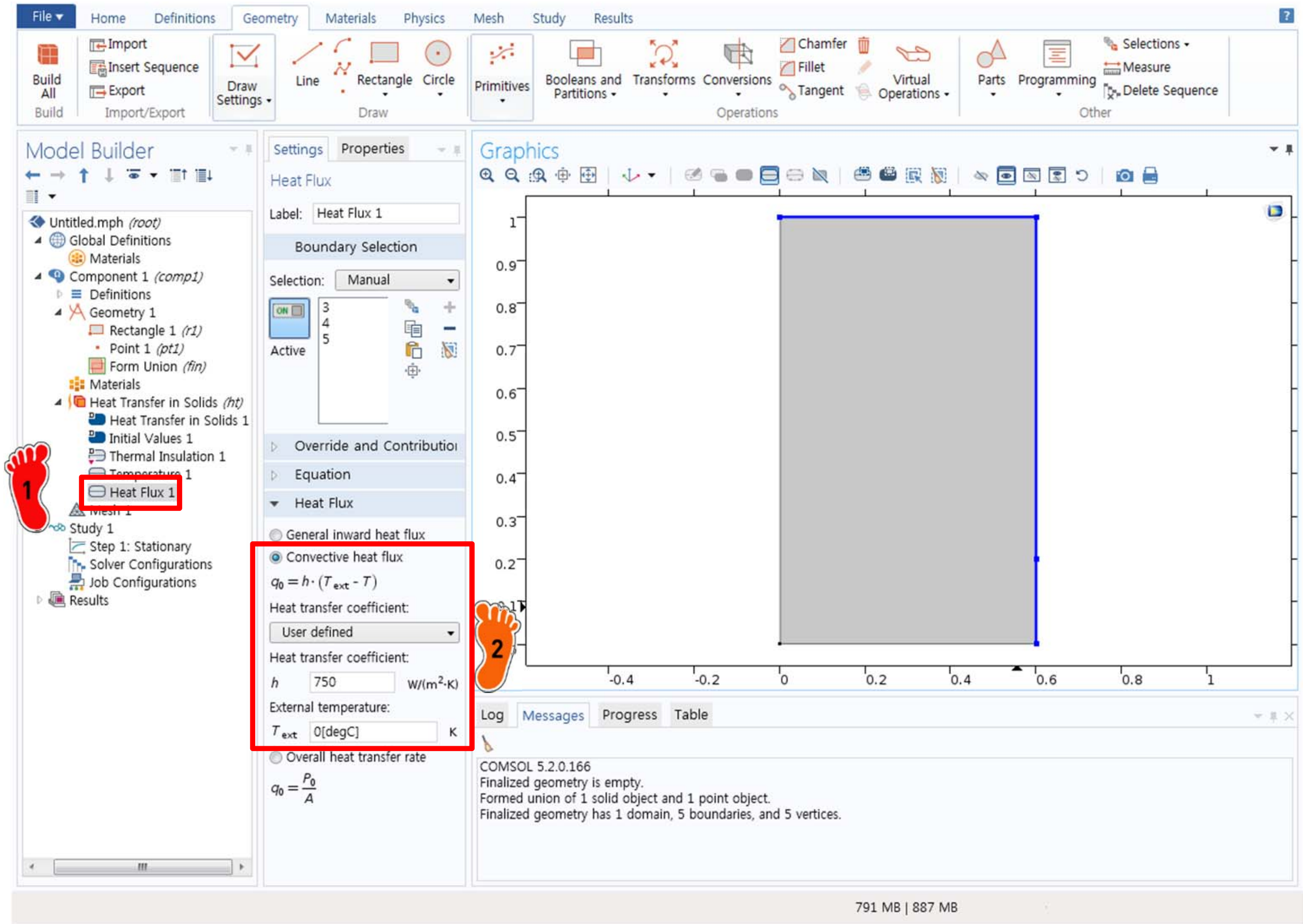
2 k: 52 입력

BOUNDARY CONDITION



1. Temperature 경계조건 생성
2. 100 도를 2번 경계에 입력

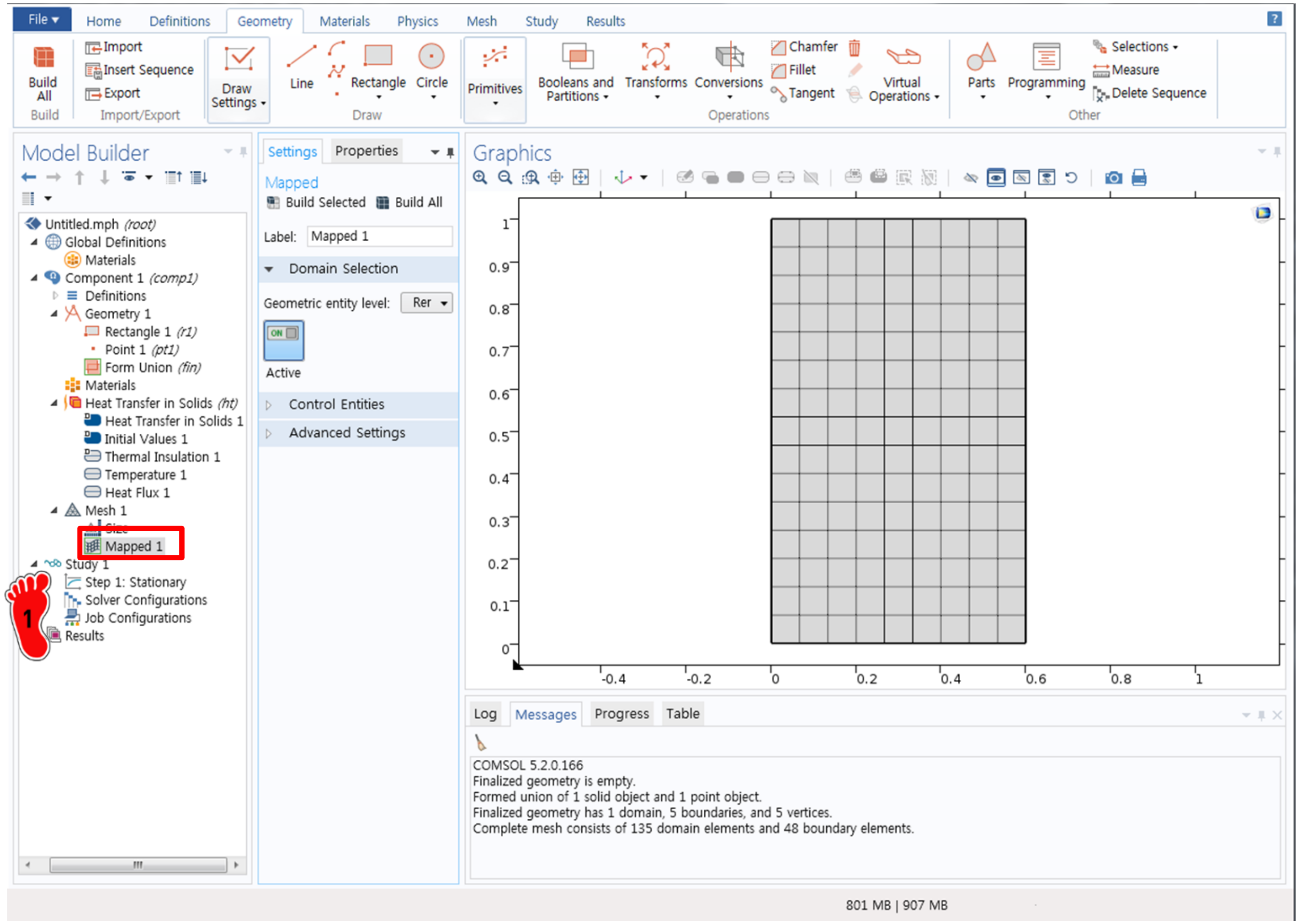
BOUNDARY CONDITION



1 Heat flux 경계조건 생성

2 Convective heat flux메뉴를 이용하여 대류 열전달 계수 750, 외기온도 0 도 입력

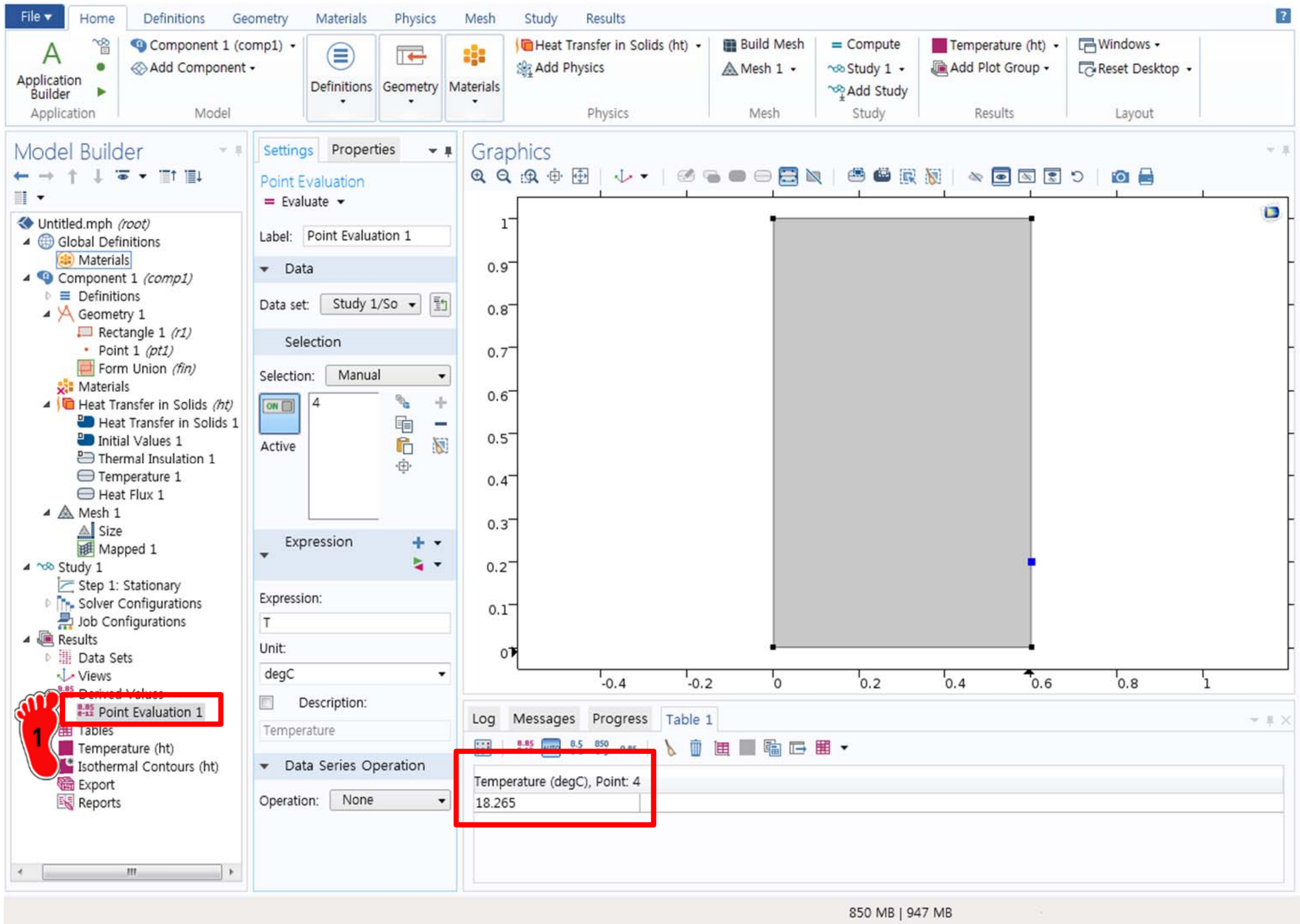
MESH



1 Mapped mesh 기능을 이용하여 요소 생성

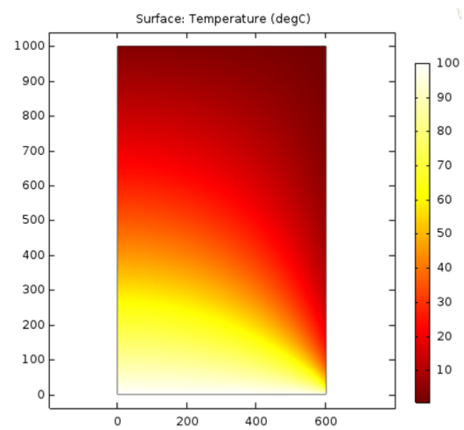
그 후, 해석실행

POST-PROCESSING



1 Derived Values 의 Point Evaluation 기능을 이용하여 4번 절점의 온도를 계산

결과값: 18.26504 도



CONTENTS

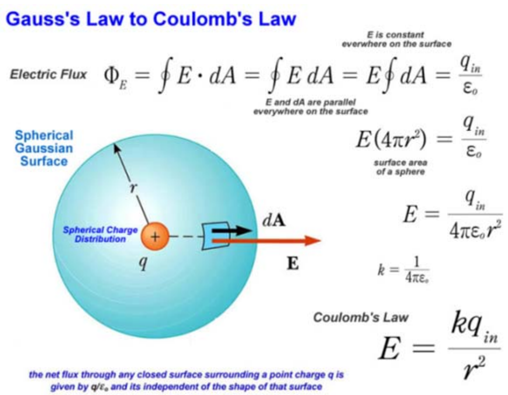
- **Heat Transfer**
  - ✓ **2D/3D model**
  - ✓ **Weak Formulation**
- **<u>Electromagnetics</u>**
  - ✓ **Resistance calculation**
  - ✓ **C-core Actuator**
- **Assignment**

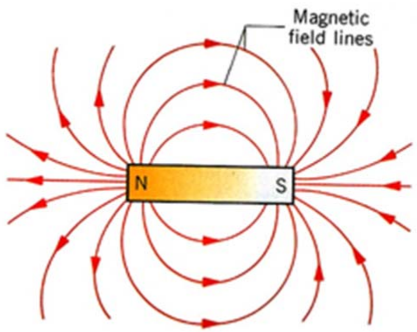
ELECTROMAGNETICS

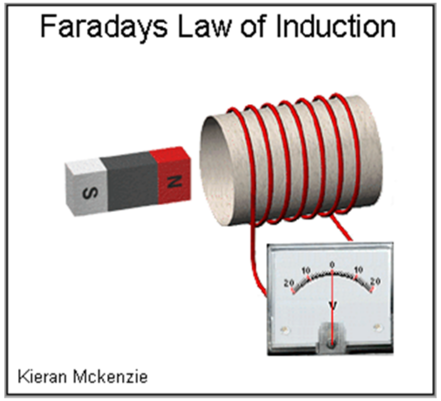
Maxwell equations

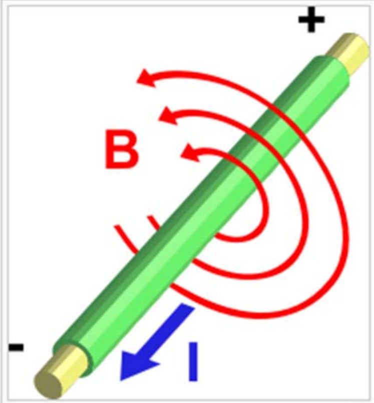
Formulation in terms of *free* charge and current

Name	Differential form	Integral form
Gauss's law	$\nabla \cdot \mathbf{D} = \rho_f$	$\oiint_{\partial V} \mathbf{D} \cdot \mathrm{d}\mathbf{A} = Q_f(V)$
Gauss's law for magnetism	$\nabla \cdot \mathbf{B} = 0$	$\oiint_{\partial V} \mathbf{B} \cdot \mathrm{d}\mathbf{A} = 0$
Maxwell–Faraday equation (Faraday's law of induction)	$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\oint_{\partial S} \mathbf{E} \cdot \mathrm{d}\mathbf{l} = -\frac{\partial \Phi_S(\mathbf{B})}{\partial t}$
Ampère's circuital law (with Maxwell's correction)	$\nabla \times \mathbf{H} = \mathbf{J}_f + \frac{\partial \mathbf{D}}{\partial t}$	$\oint_{\partial S} \mathbf{H} \cdot \mathrm{d}\mathbf{l} = I_{f,S} + \frac{\partial \Phi_S(\mathbf{D})}{\partial t}$









An electric current produces a magnetic field.

MAGNETIC AND ELECTRIC FIELDS

$$\begin{cases} \text{electric} \begin{cases} \text{field intensity: } \mathbf{E} \\ \text{displacement/flux density: } \mathbf{D} \\ \text{charge density: } \rho \end{cases} \\ \text{current density: } \mathbf{J} \\ \text{magnetic} \begin{cases} \text{field intensity: } \mathbf{H} \\ \text{displacement/flux density: } \mathbf{B} \end{cases} \end{cases} \rightarrow \begin{cases} \text{Maxwell-Ampere's law: } \nabla \times \mathbf{H} = \mathbf{J} + \dfrac{\partial \mathbf{D}}{\partial t} \\ \text{Faraday's law: } \nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t} \\ \text{Gauss's law (electric form): } \nabla \cdot \mathbf{D} = \rho \\ \text{Gauss's law (magnetic form)} \nabla \cdot \mathbf{B} = 0 \end{cases}$$

$$\text{potentials} \rightarrow \begin{cases} \text{electric scalar potential } V: \ \mathbf{E} = -\nabla V - \dfrac{\partial \mathbf{A}}{\partial t} \\ \text{magnetic vector potential } \mathbf{A}: \ \mathbf{B} = \nabla \times \mathbf{A} \end{cases}$$

$$\text{constitutive relations} \rightarrow \begin{cases} \mathbf{D} = \varepsilon_0 \varepsilon_r \mathbf{E} \ \begin{cases} \varepsilon_0: \ \text{permittivity of vacuum} \left(= \dfrac{1}{c_0{}^2 \mu_0} = 8.854 \times 10^{-12} \left[F/m\right] \approx \dfrac{1}{36\pi} \times 10^{-9} \left[F/m\right] \right) \\ \varepsilon_r: \ \text{relative permittivity} \end{cases} \\ \mathbf{B} = \mu_0 \mu_r \mathbf{H} \ \begin{cases} \mu_0: \ \text{permeability of vacuum} \left(4\pi \times 10^{-7} \left[H/m\right]\right) \\ \mu_r: \ \text{relative permittivity} \end{cases} \\ \mathbf{J} = \sigma \mathbf{E} \end{cases}$$

σ: electrical conductivity

c_0: velocity of an electromagnetic wave in vacuum

CONTENTS

- **Heat Transfer**
  - ✓ **2D/3D model**
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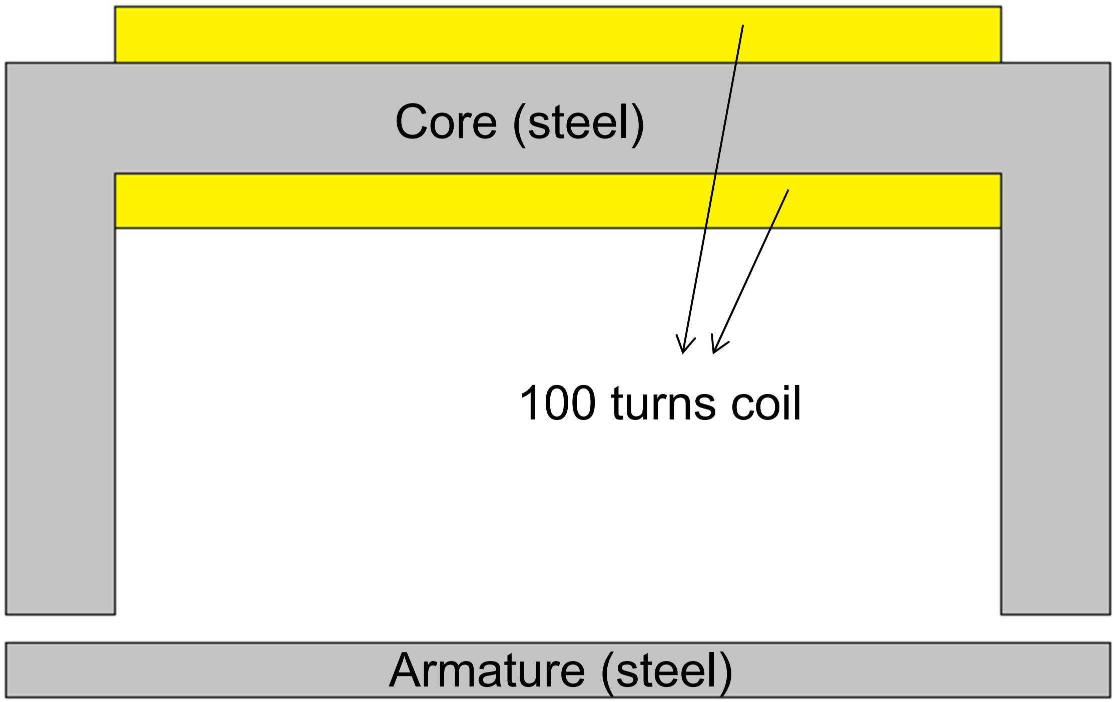
  - ✓ **Resistance calculation**
  - ✓ **C-core Actuator**
- **Assignment**

C-CORE ACTUATOR

Geometry Information



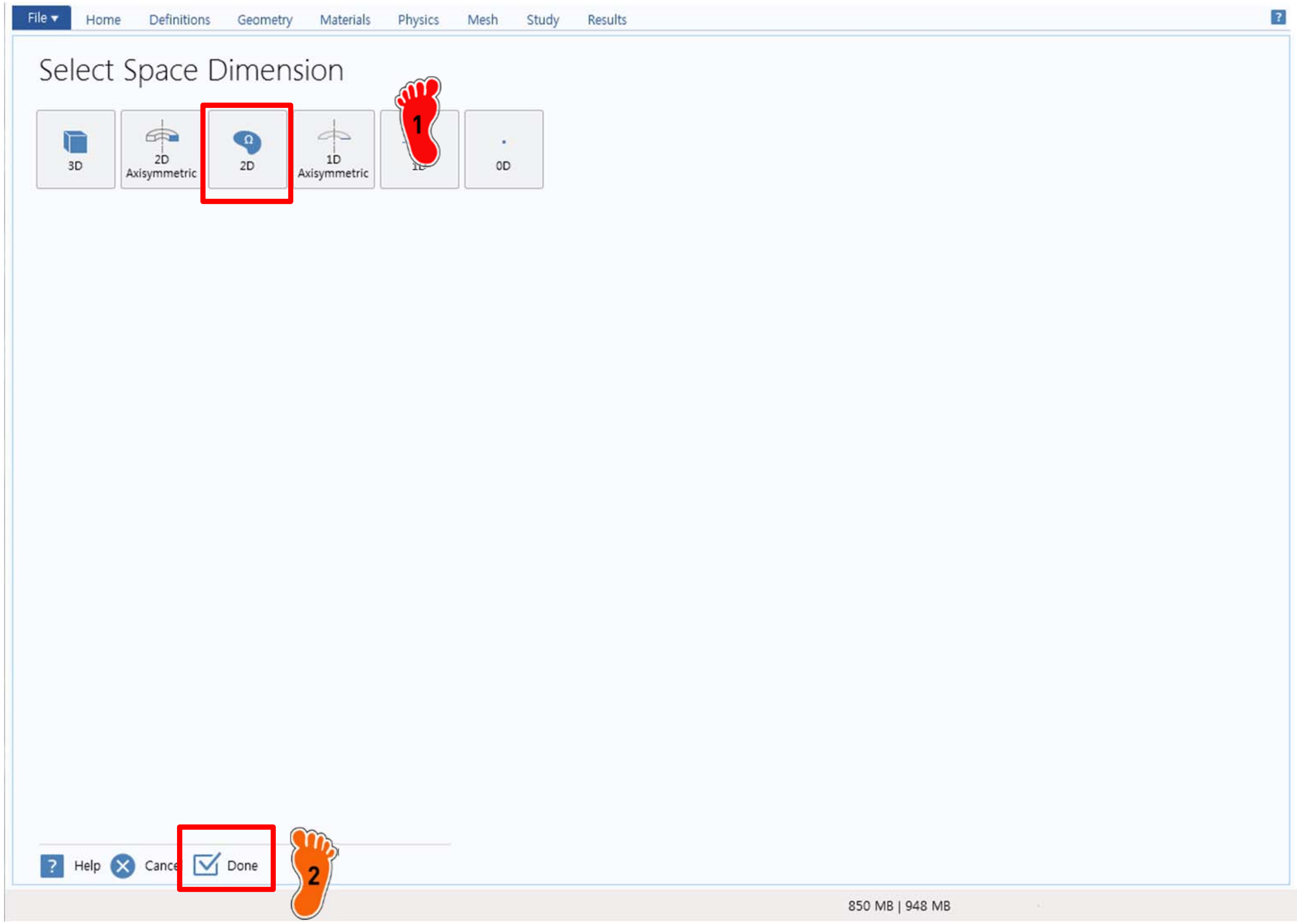
Input Information

Current: 1 [A]
Turns: 100
Relative permeability: 10000

What is the magnetic flux density in the air gap?

Analytic solution: 2.51e-2 [T]

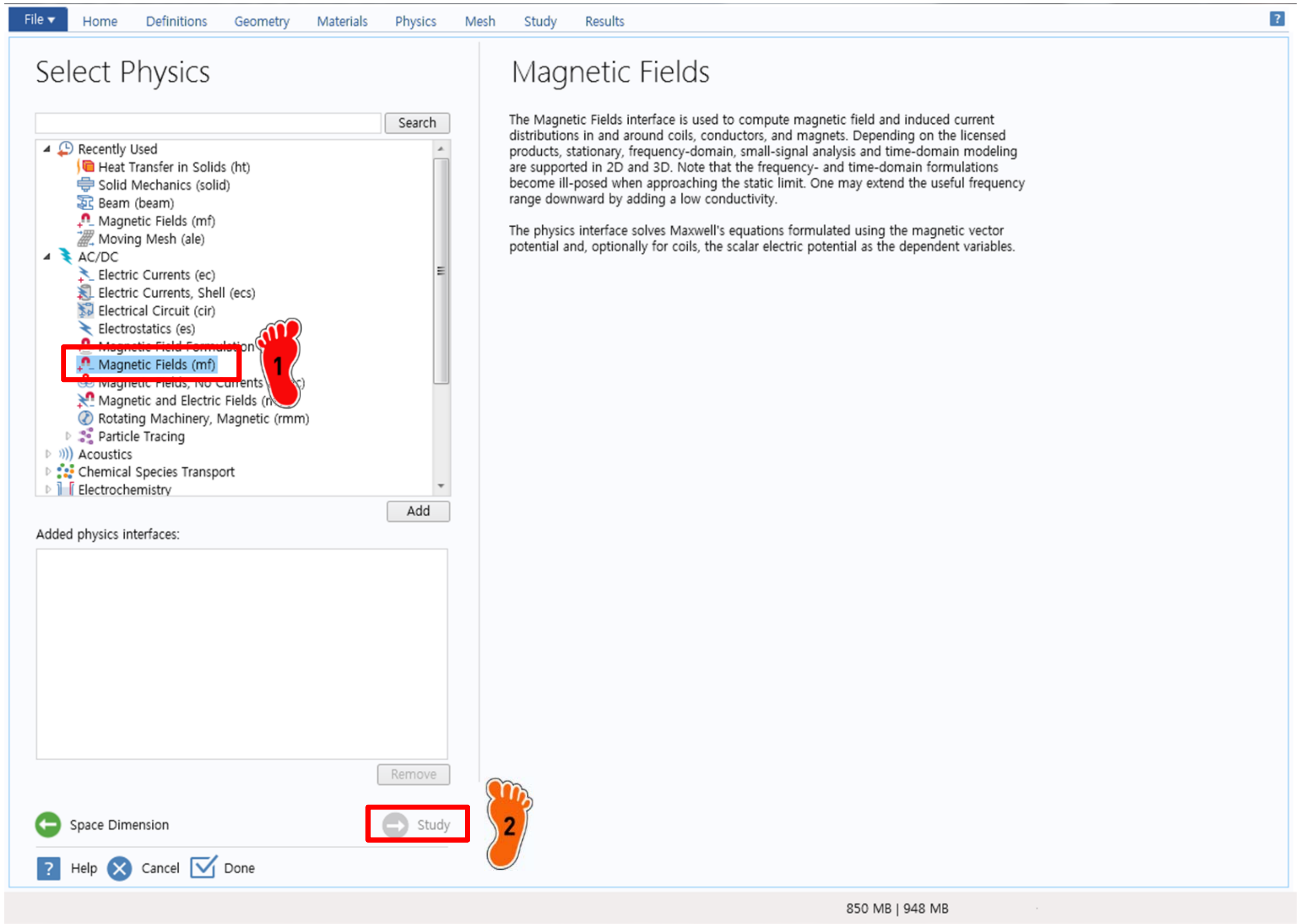
DIMENSION SELECTION



1 2D 선택

2 Done클릭

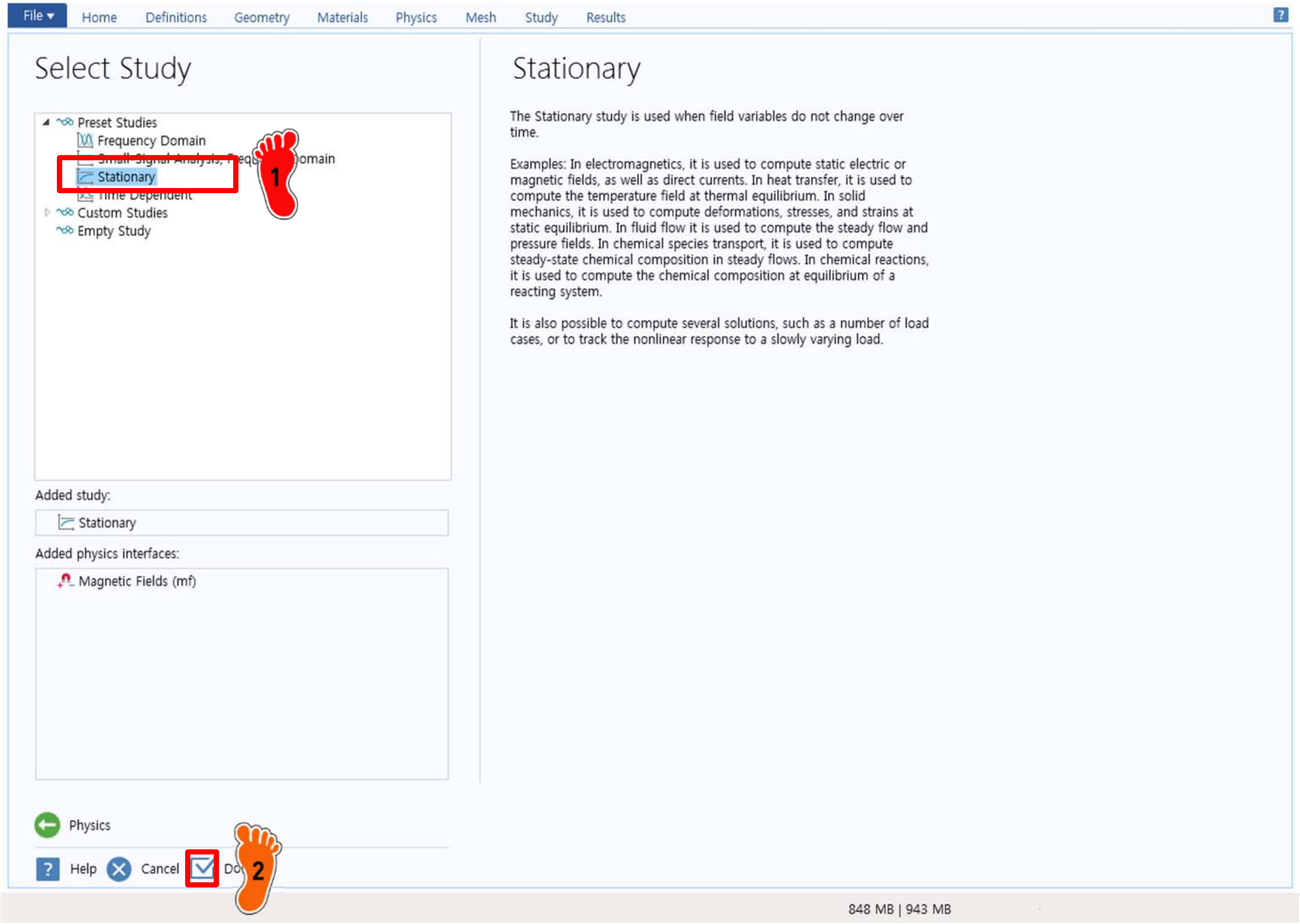
PHYSICS SELECTION



1 AC/DC > Magnetic Fields 선택

2 화살표 클릭

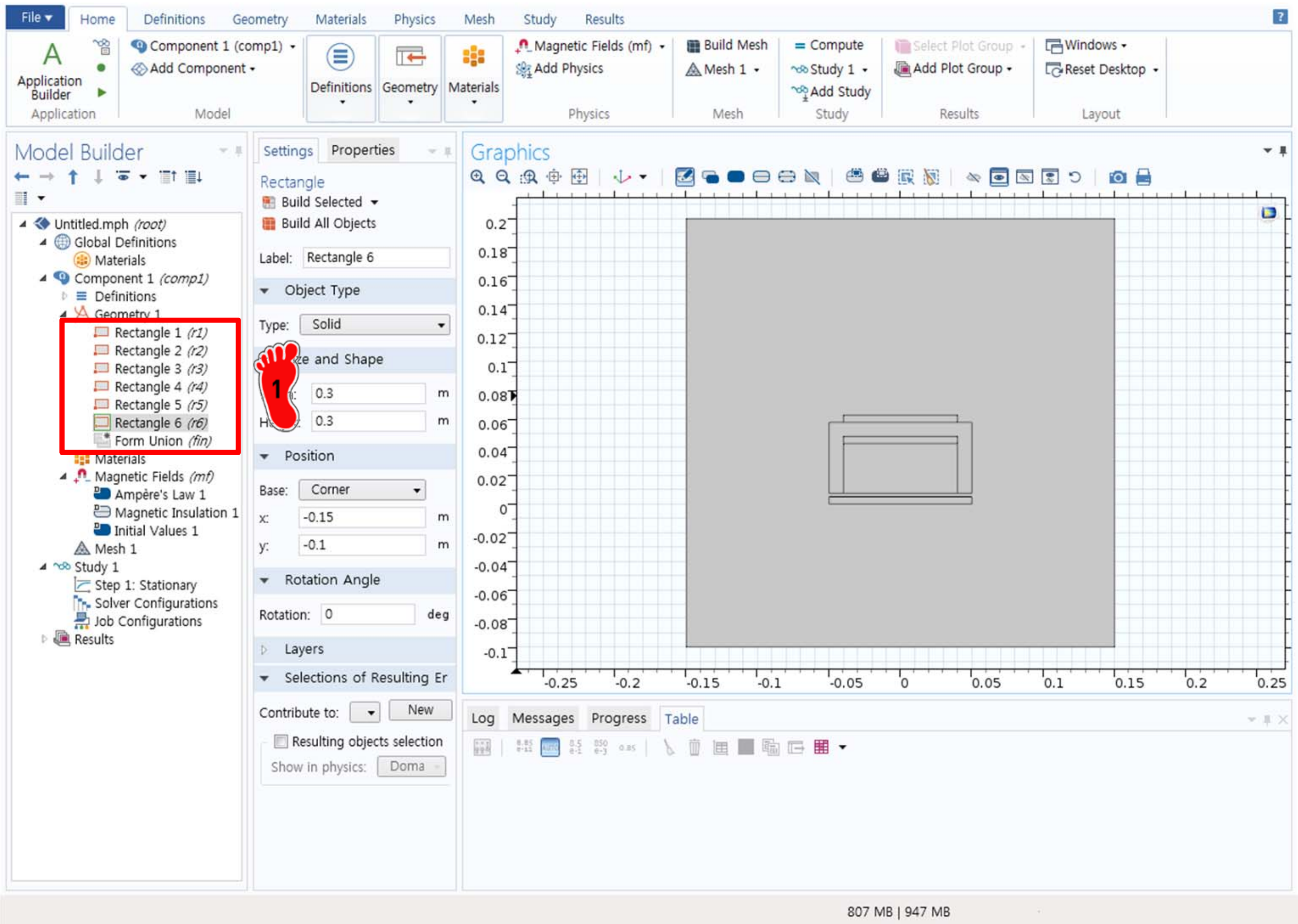
STUDY TYPE SELECTION



1 Stationary 선택

2 Done 클릭

GEOMETRY CREATION



1 사각형 6개로 주어진 기하 형상 생성

Rec1
Size(0.1, 0.005)
base(-0.05, 0)

Rec2
Size(0.1, 0.05)
base(-0.05, 0.0075)

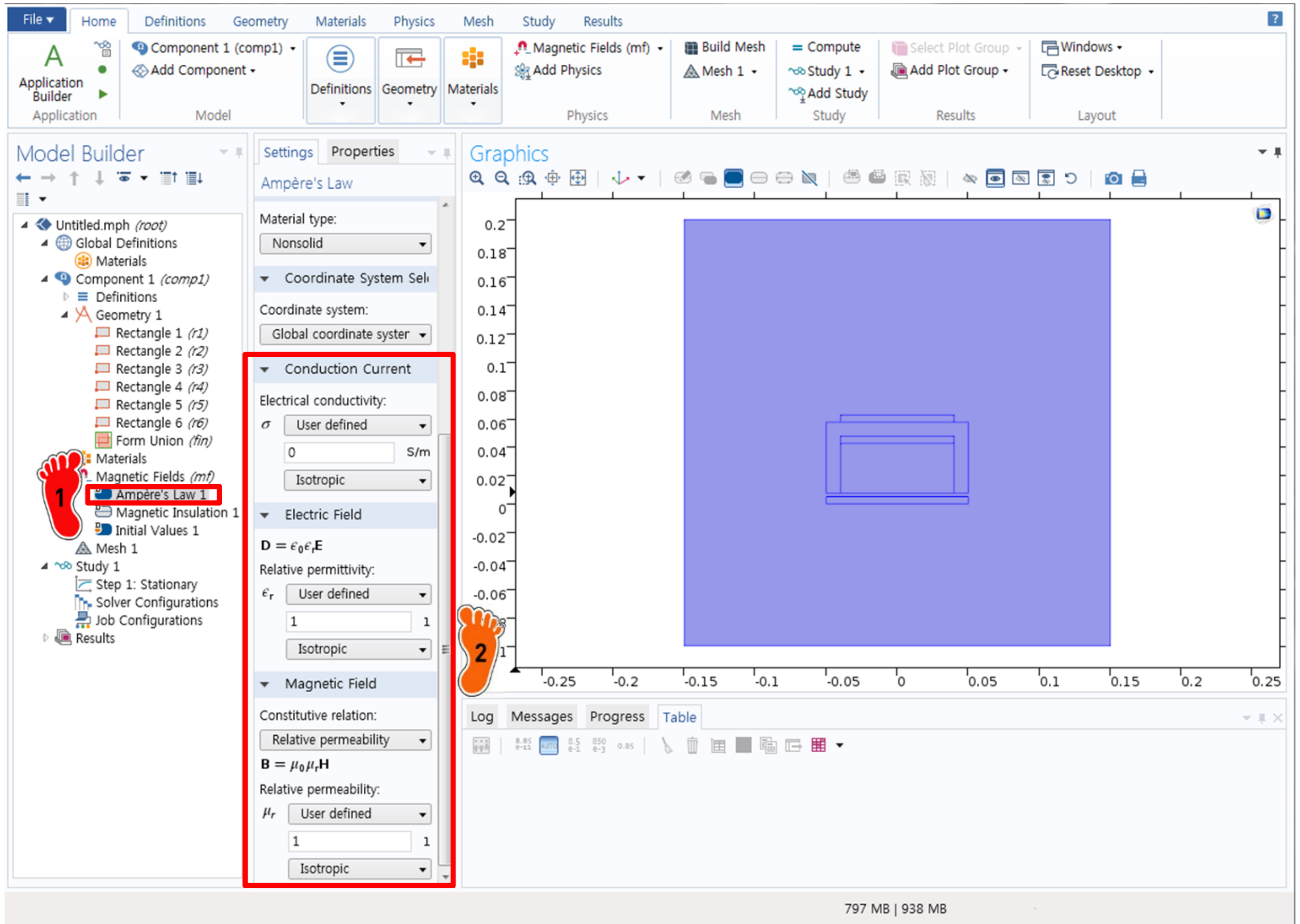
Rec3
Size(0.08, 0.04)
base(-0.04, 0.0075)

Rec4
Size(0.08, 0.005)
base(-0.04, 0.0425)

Rec5
Size(0.08, 0.005)
base(-0.04, 0.0575)

Rec6
Size(0.3, 0.3)
base(-0.15, -0.1)

MATERIAL PROPERTY

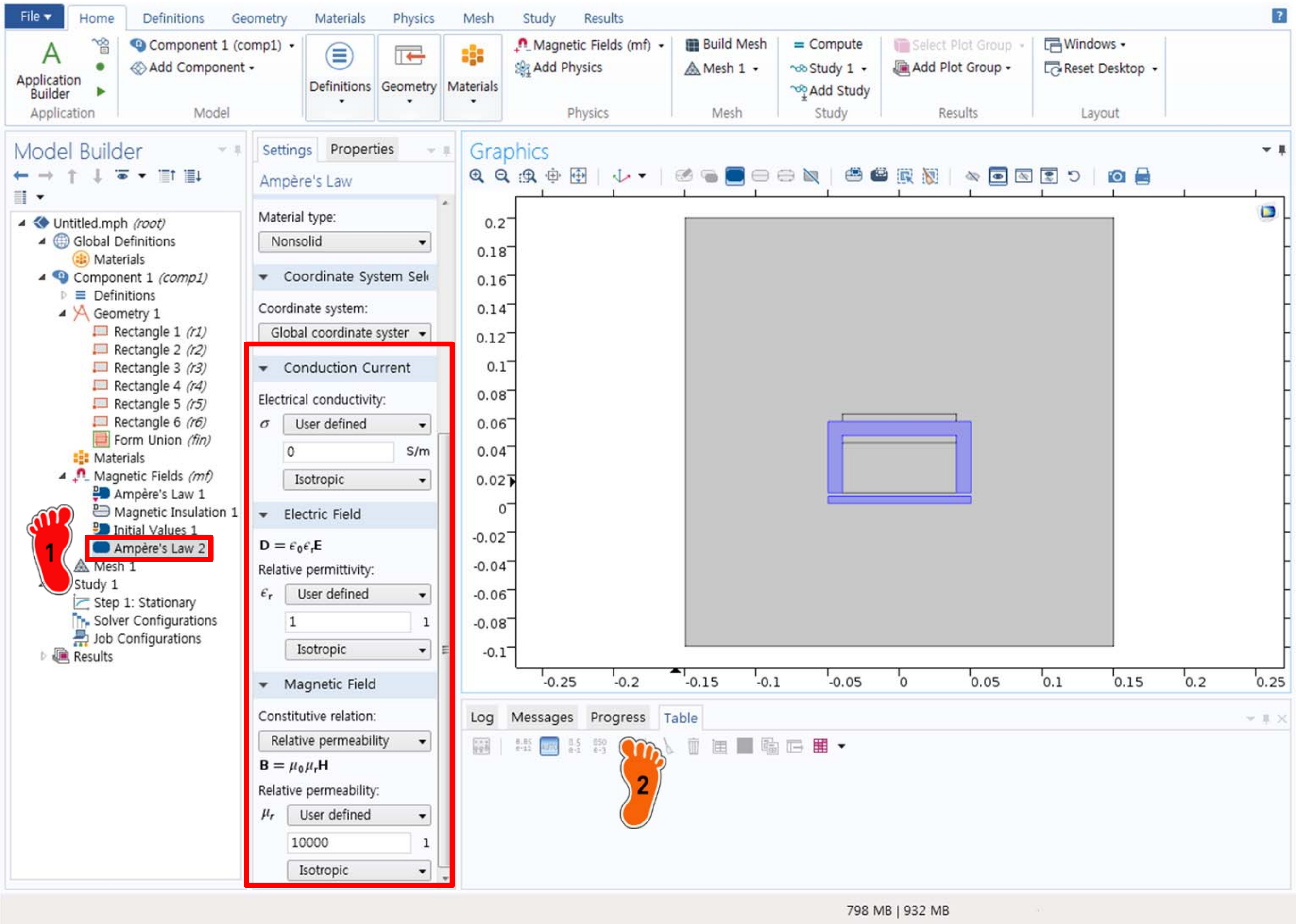


1 Ampere`s Law 1 클릭

2 Conductivity: 0
Relative permittivity: 1
Relative permeability: 1

입력

MATERIAL PROPERTY



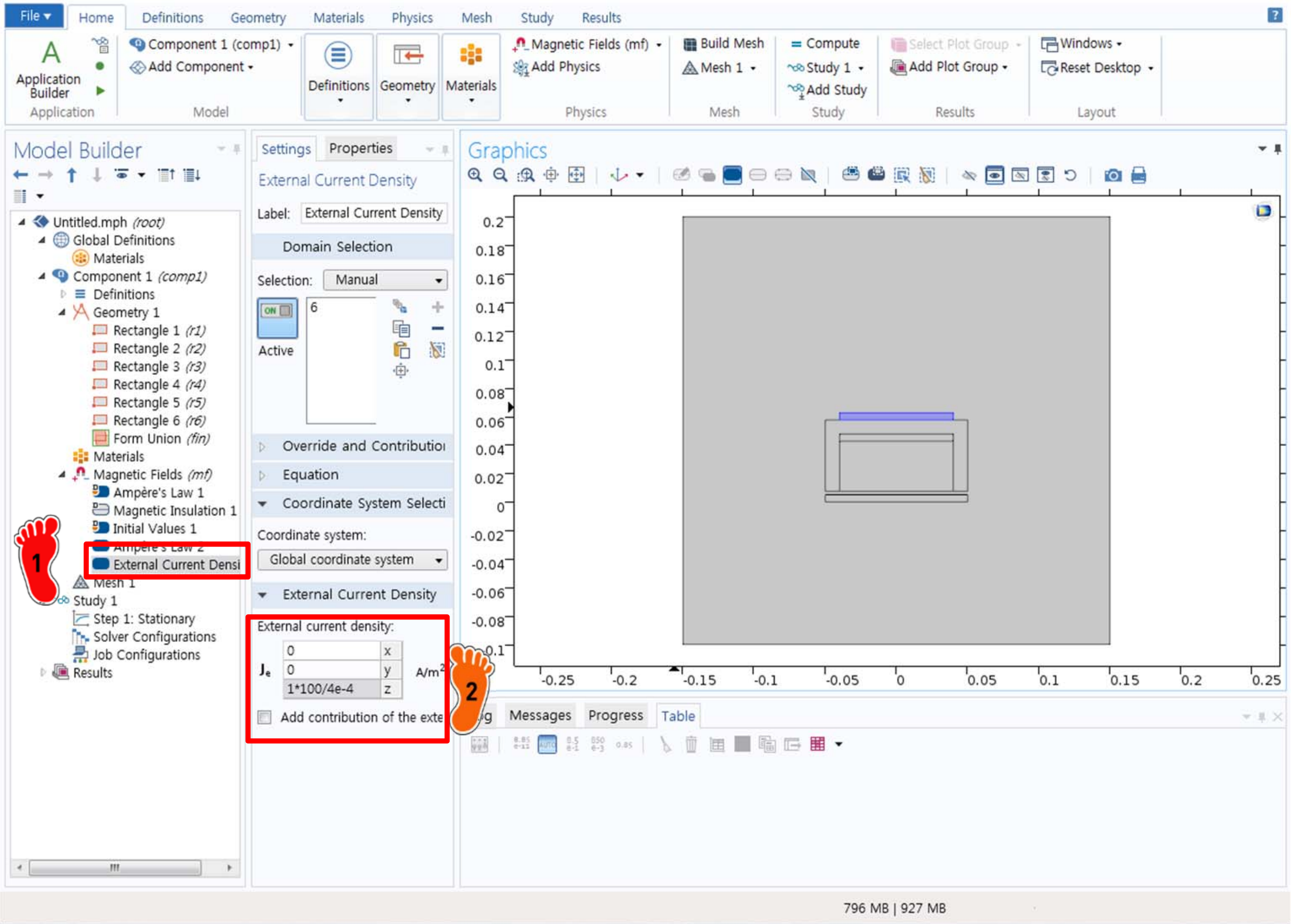
1 Ampere`s Law 2 생성

2 2, 3 번 도메인 선택

Conductivity: 0
Relative permittivity: 1
Relative permeability: 10000

입력

CURRENT DENSITY



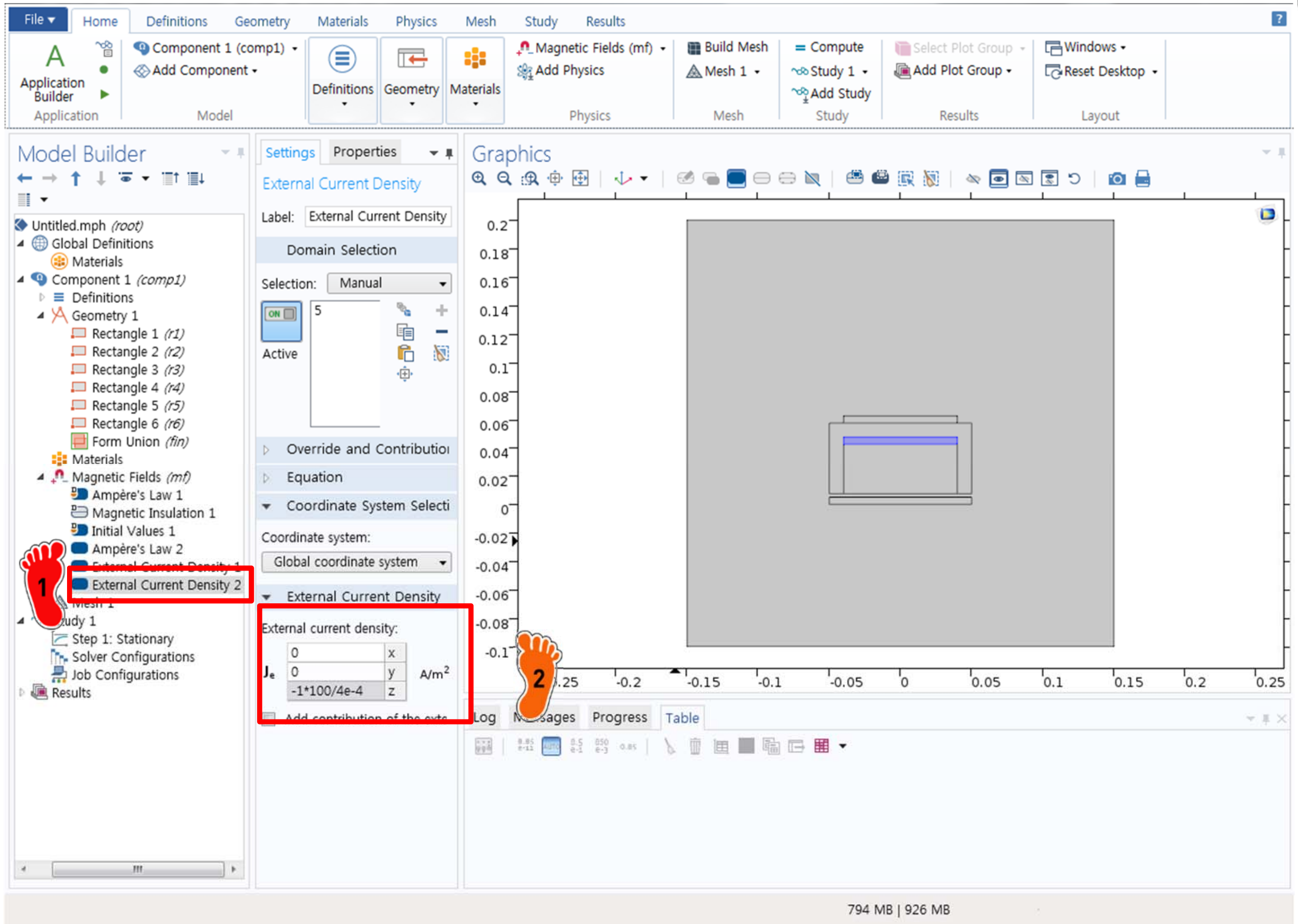
1 External Current Density 생성

2 6번 도메인 선택 후

z 방향: 1*100/4e-4

입력

CURRENT DENSITY



1 External Current Density 생성

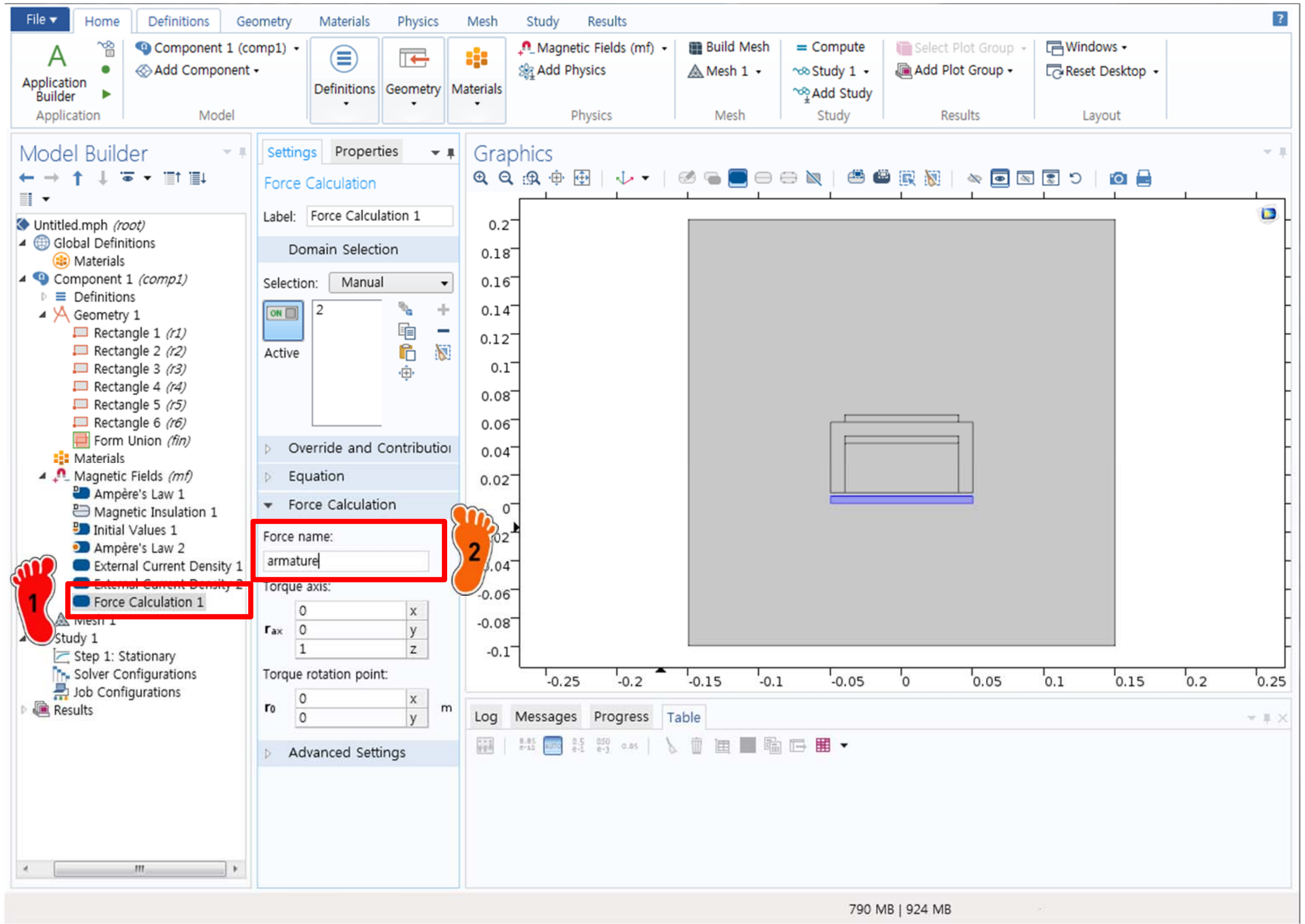
2 5번 도메인 선택 후

z 방향: -1*100/4e-4

입력

코어를 감고 있는 전선 모델링 완료

FORCE CALCULATION



1 Force Calculation 생성

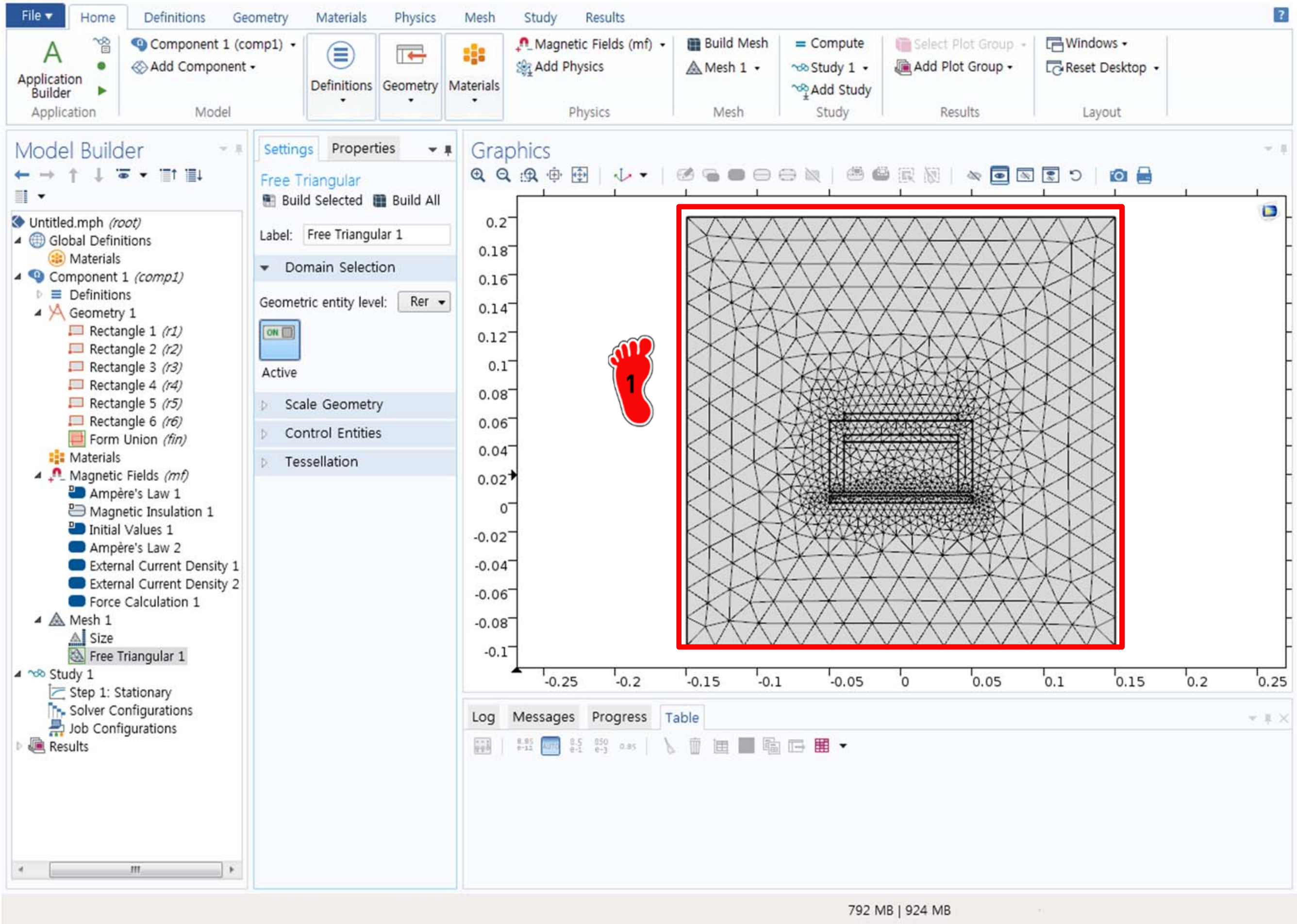
2 2번 도메인 선택 후

Force name: armature

입력

전류가 인가되고 C-core가 전자석의 역할을 할 때의 자기력을 계산하기 위한 작업

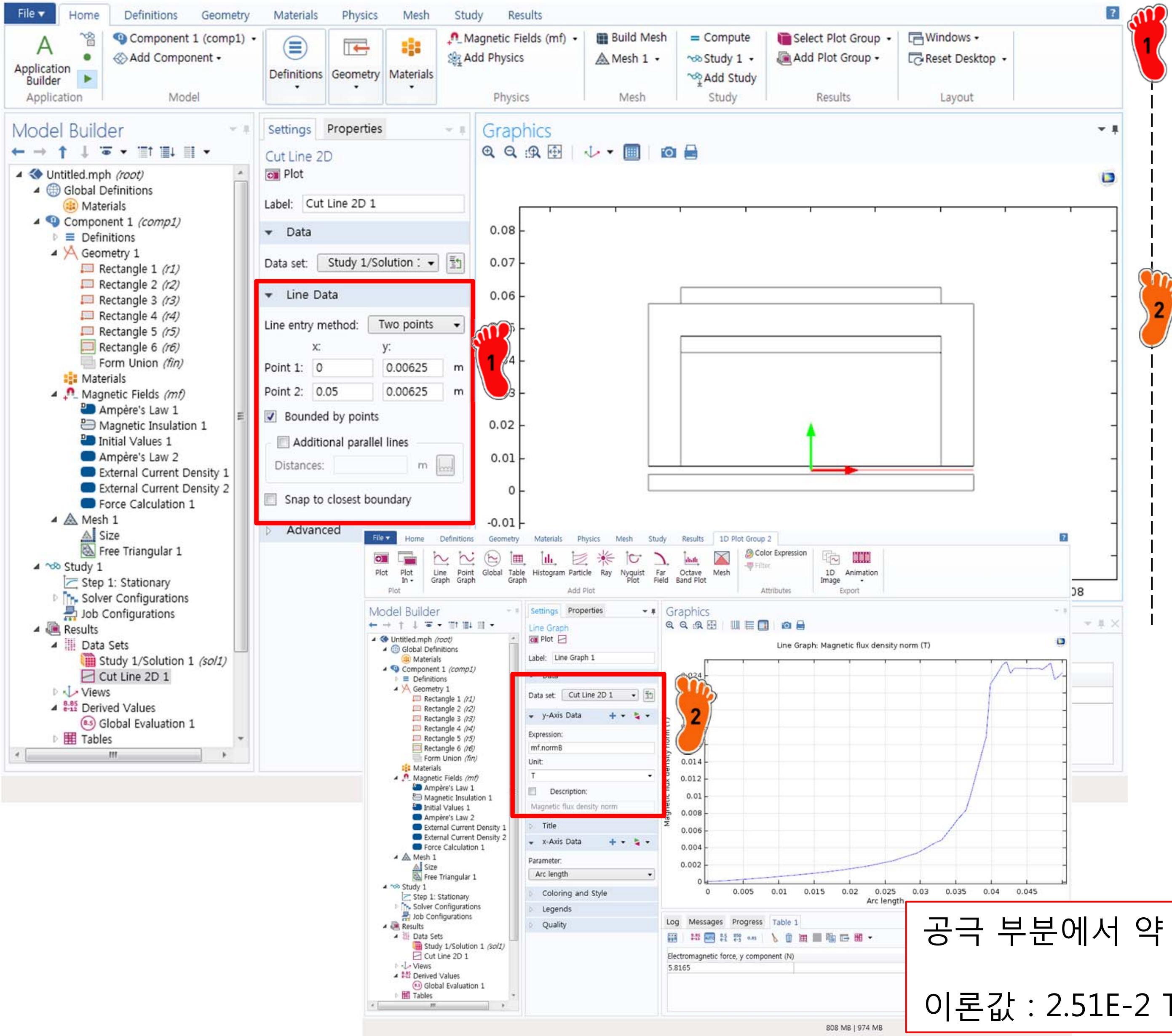
MESH CREATION



1 기본 삼각메쉬 생성 후,

해석 실행

RESULTS



Data Sets 에서 Cut Line 2D

Point 1 : (0, 0.00625)
Point 1 : (0.05, 0.00625)

Plot 클릭 -> Cut Line 확인

1D plot -> Line graph

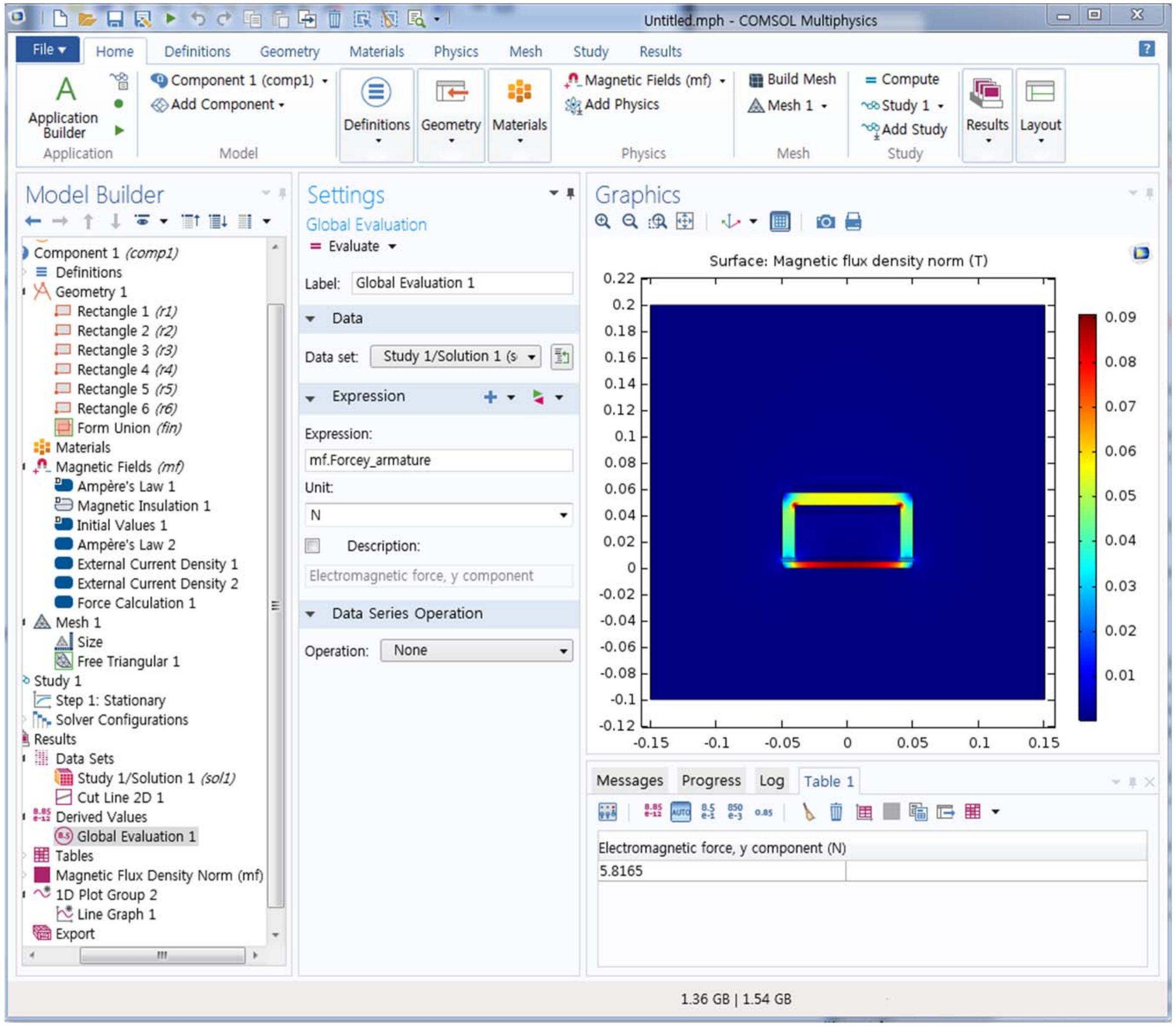
Data sets -Cut Line 2D

설정하여 공극의 자속확인

공극 부분에서 약 2.55E-2 T 의 자속 발생

이론값 : 2.51E-2 T

RESULTS



Derived Values -> Global Evaluation 에서 mf.Forcey_armature 를 입력하여 발생 자기력 확인

형식: mf.Force<방향>_<이름>

Electromagnetic force, y component (N)
5.8165

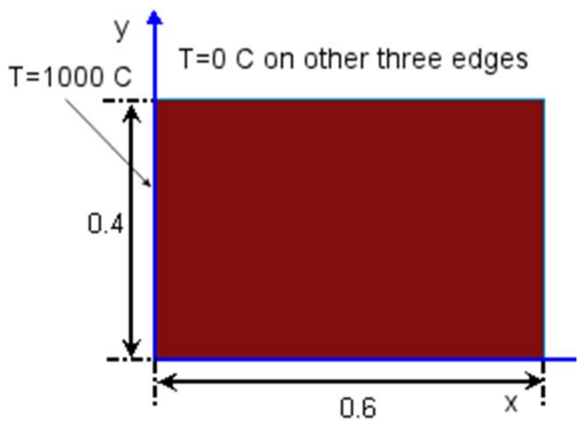
그 외, 코어 내부의 자속 분포, 자속의 방향 등 확인

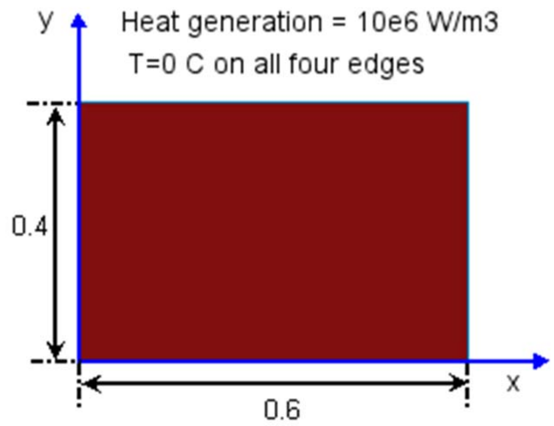
HOMEWORK: HEAT TRANSFER

Steady State Temperature Distribution in a Plate

A rectangular plate (0.6m x 0.4m) is subjected to (a) prescribed temperature distribution, and (b) internal heat generation. Determine the steady state temperature distribution in the plate at predefined locations A (x= 0.2m, y=0.2m) and B (x= 0.3m, y = 0.2m).

- For Study1, the temperature at one edge of the plate is maintained at 1000°C, while the temperature at the other three edges is 0°C. Dimensions are shown in m.
- For Study 2, the temperature at all four edges is 0°C. Heat generation of 10^6 W/m^3 is applied to the whole plate.

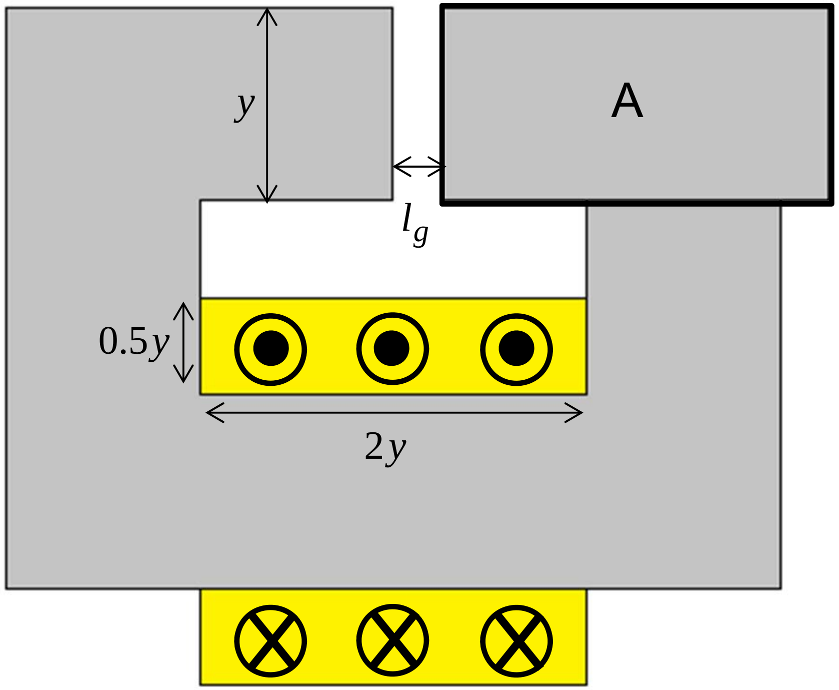




Thickness: 0.1m
Mesh size: 1 cm
Specific heat(C): 460J/Kg°K
Thermal conductivity(K): 52W/m°K
Density(ρ): 7850 kg/m^3

	NAFEMS
Target point	
Study 1 (x= 0.2m, y=0.2m)	260.5 ^{0}C
Study 2 (x= 0.3m, y=0.2m)	310.1^{0}C

HOMEWORK: MAGNETIC



Find attractive force of armature A.

Geometry Property

$$z = 0.1\ \text{m}$$
$$y = 0.2\ \text{m}$$
$$i = 10\ \text{A}$$
$$N = 50\ \text{turns}$$
$$l_g = 0.05\ \text{m}$$

$$B_g = Ni\frac{\mu_0}{l_g}$$

$$f_x = \frac{1}{2}\frac{B_g^2}{\mu_0}yz = \frac{1}{2}\frac{\left(Ni\frac{\mu_0}{l_g}\right)^2}{\mu_0}yz$$

$$= \frac{1}{2}\frac{\left(50\times 10\frac{4\pi\times 10^{-7}}{0.05}\right)^2}{4\pi\times 10^{-7}}\times 0.1\times 0.2 = 1.2566\ \text{N}$$