COMSOL: MEMS NOTES

AKSHANSH CHAUDHARY

COMSOL Multiphysics Notes, First Edition

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Batch of 2011

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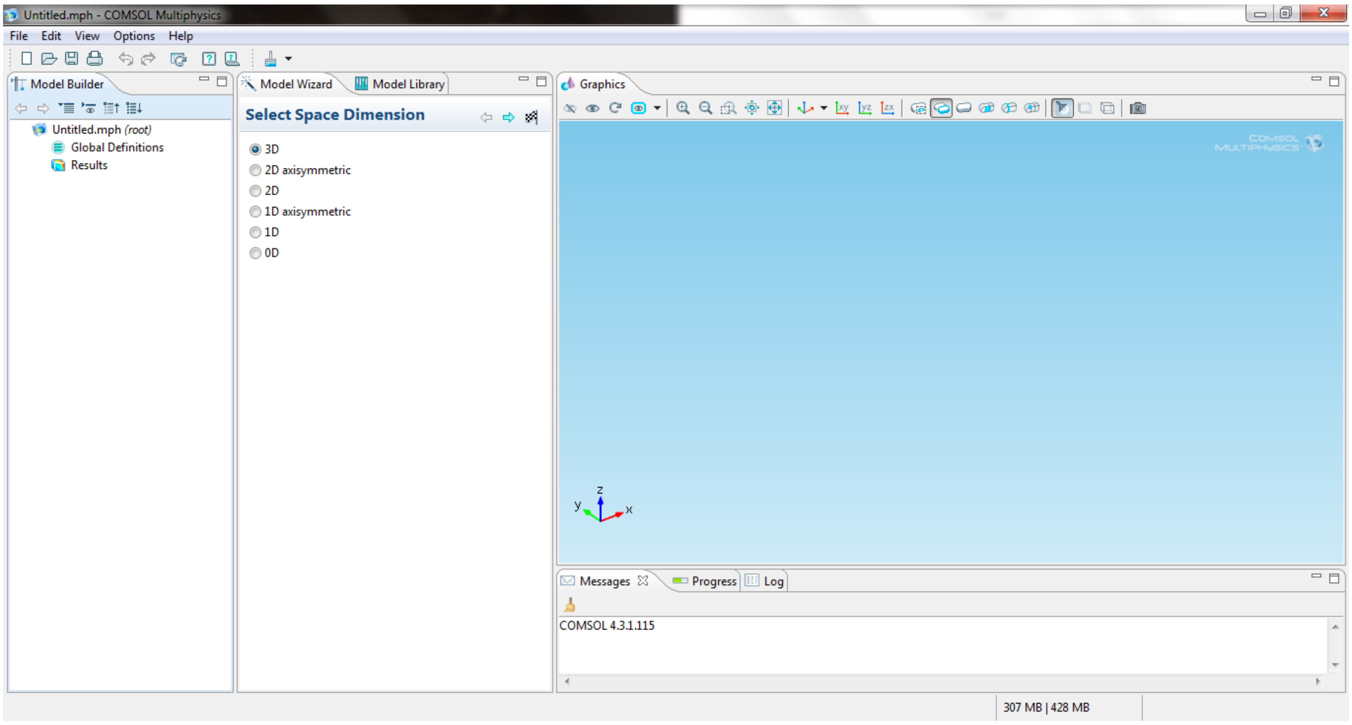
Layout design by: AC Creations © 2013

The course content was prepared during Spring, 2014.
More content available at: www.Akshansh.weebly.com

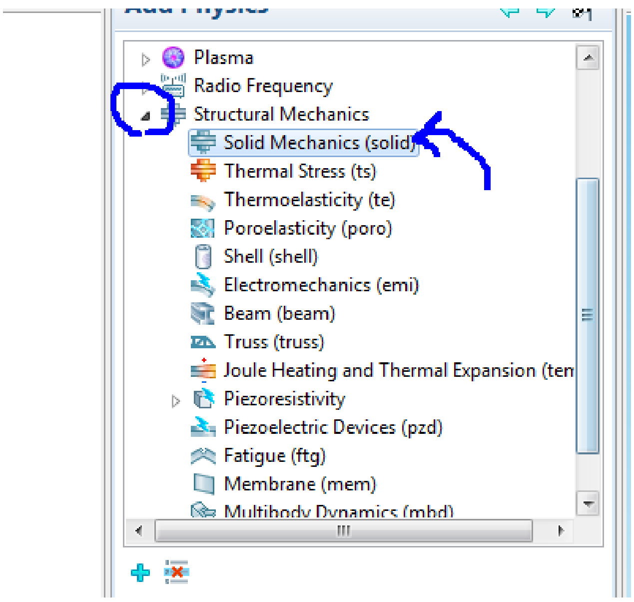
Point Load

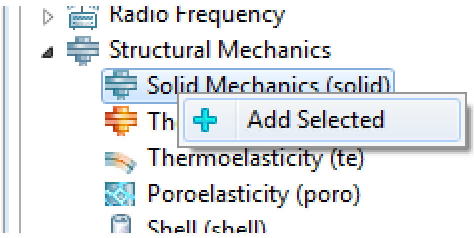
Starting Interface -

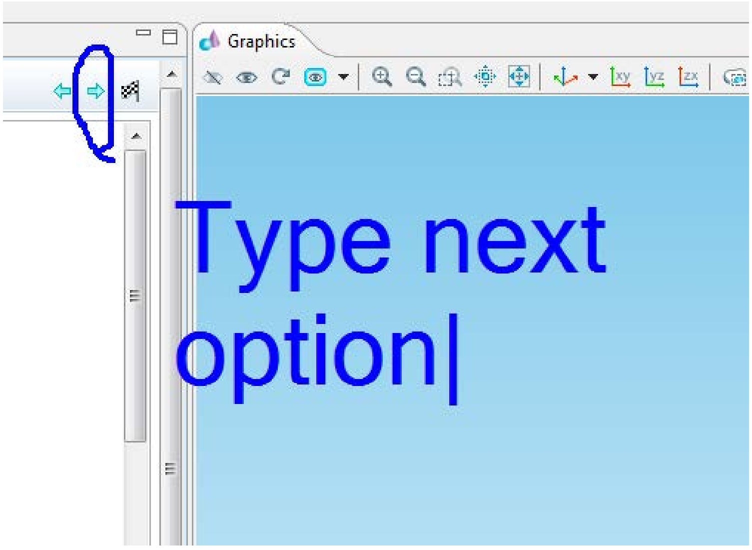


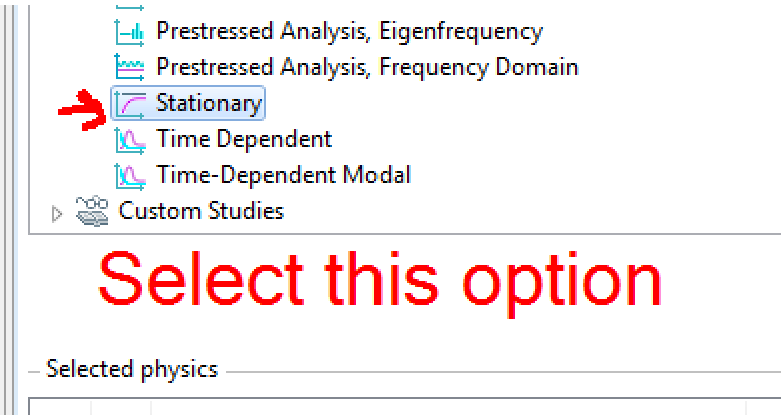
Idea:

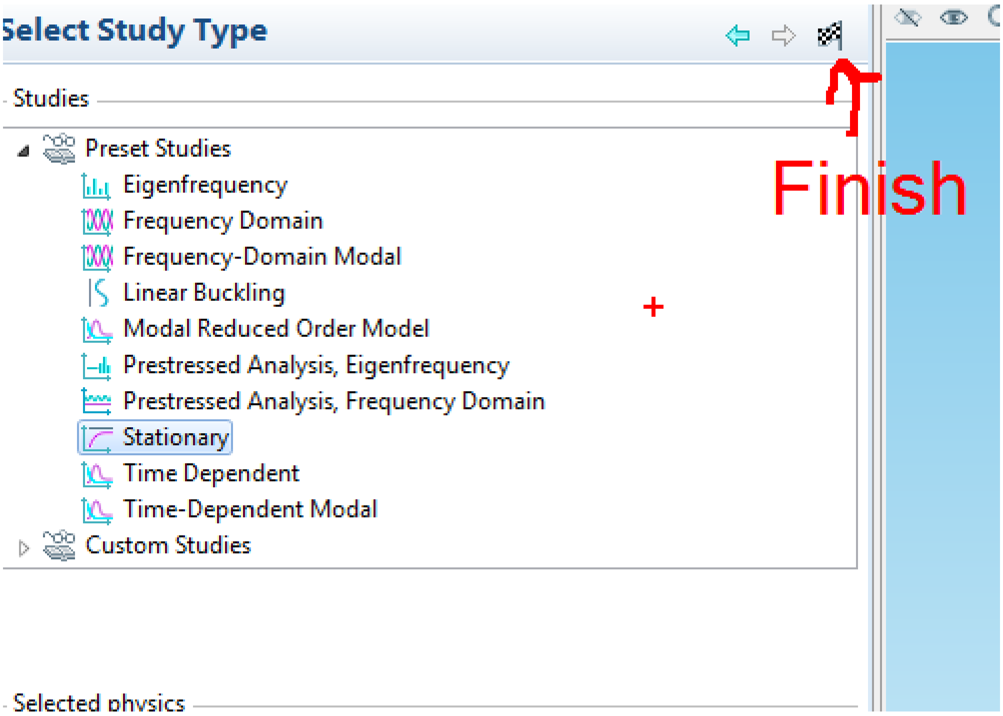
Starting with cantelever
Design a beam
Leave the second side free of the beam



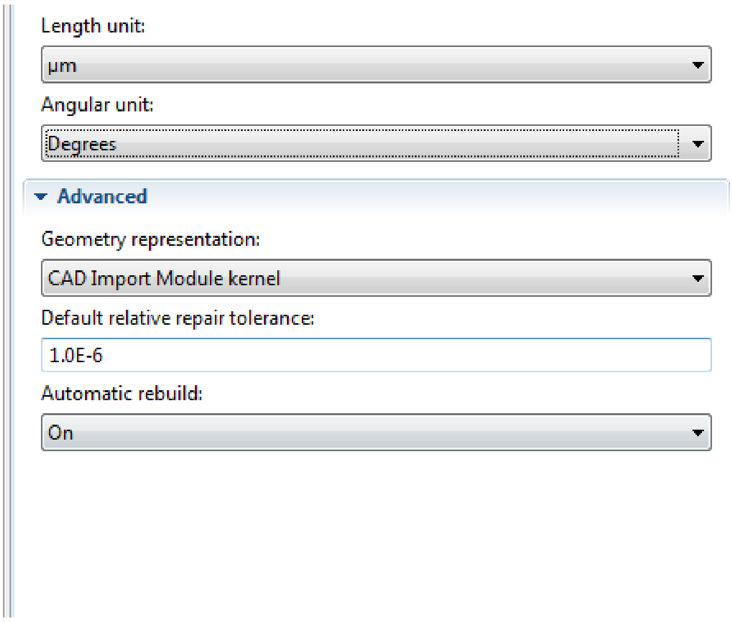

Radio Frequency
Structural Mechanics
Solid Mechanics (solid)
Add Selected
Thermoelasticity (te)
Poroelasticity (poro)
Shell (shell)

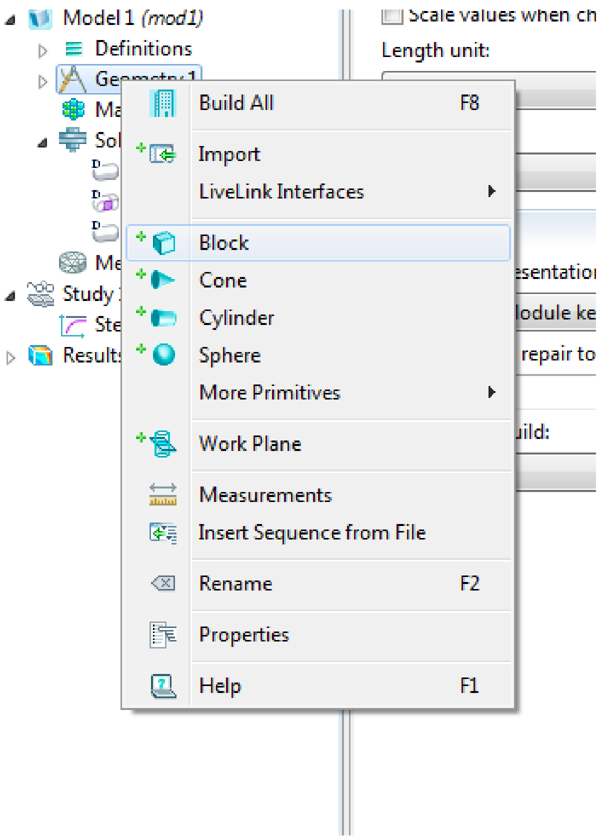

Graphics
Type next option|

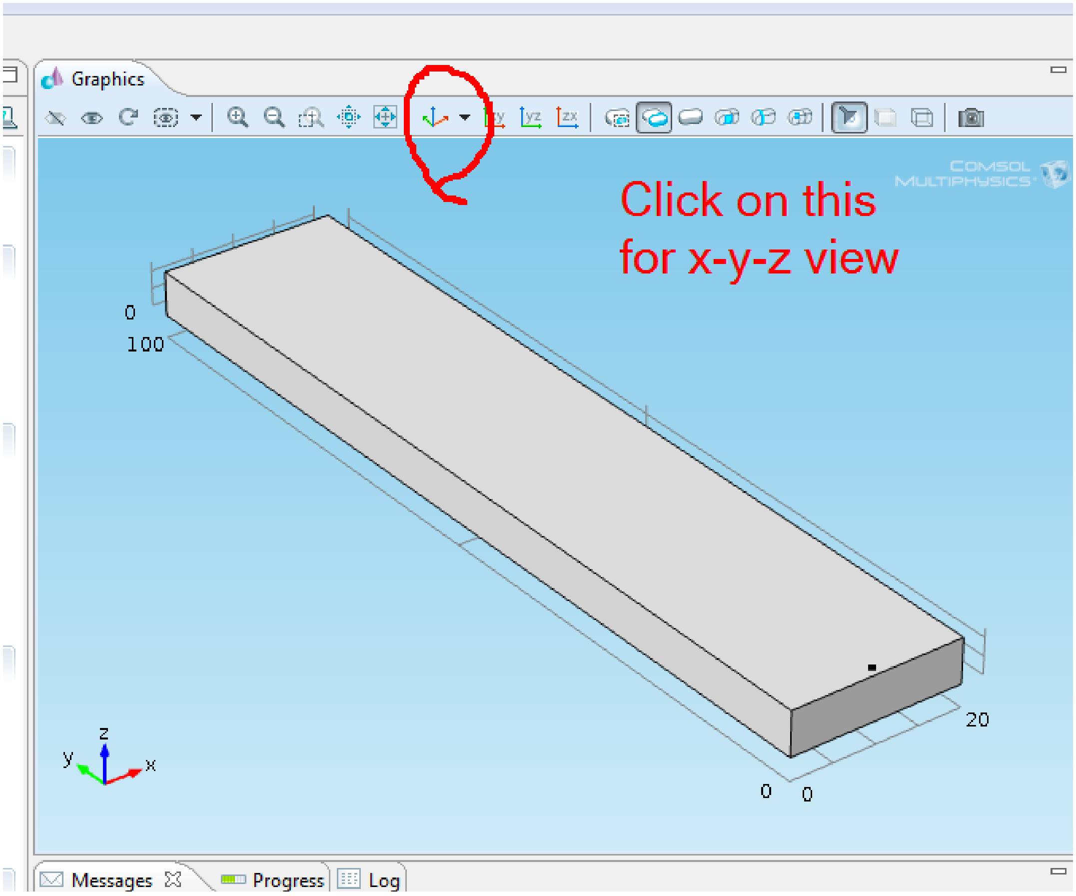

Prestressed Analysis, Eigenfrequency
Prestressed Analysis, Frequency Domain
Stationary
Time Dependent
Time-Dependent Modal
Custom Studies
Select this option
Selected physics

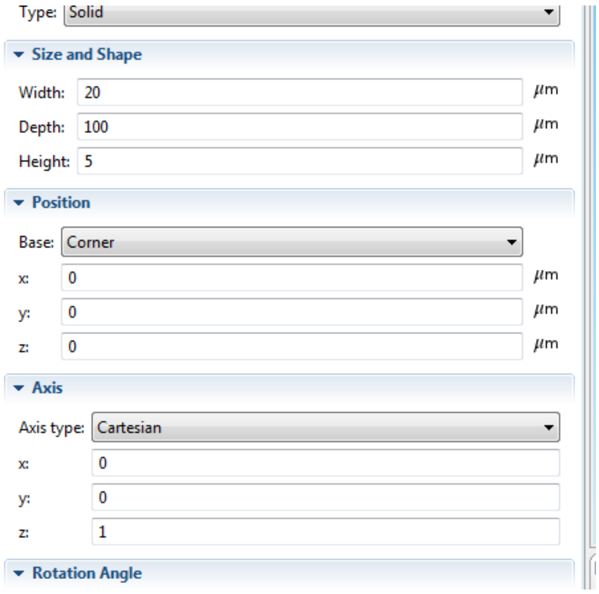


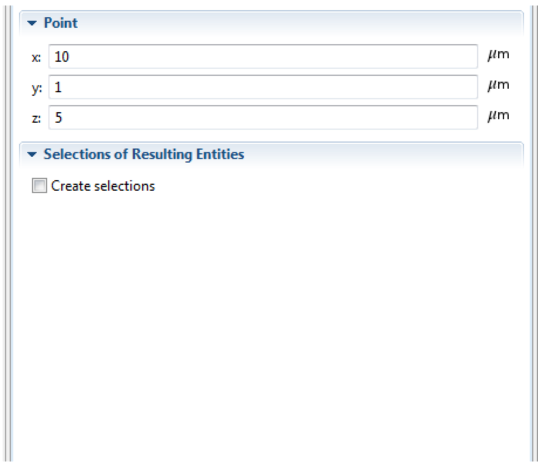
Next, select the measurement unit and other dimensions as given

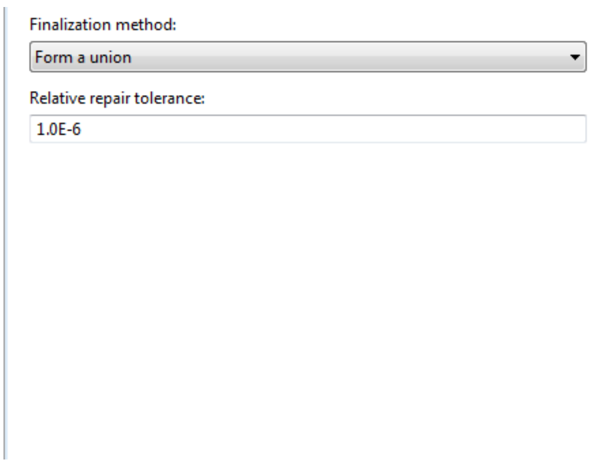


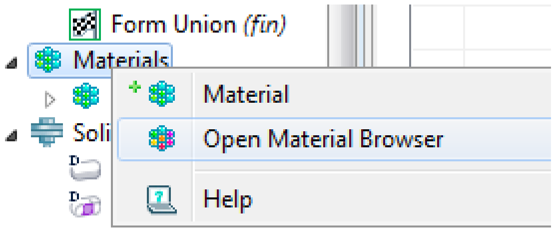

Model 1 (mod1)
Definitions
Build All F8
Import
LiveLink Interfaces
Block
Cone
Cylinder
Sphere
More Primitives
Work Plane
Measurements
Insert Sequence from File
Rename F2
Properties
Help F1
Scale values when ch
Length unit:

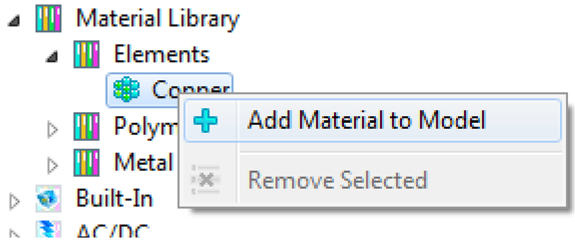

Graphics
Click on this
for x-y-z view
Messages
Progress
Log

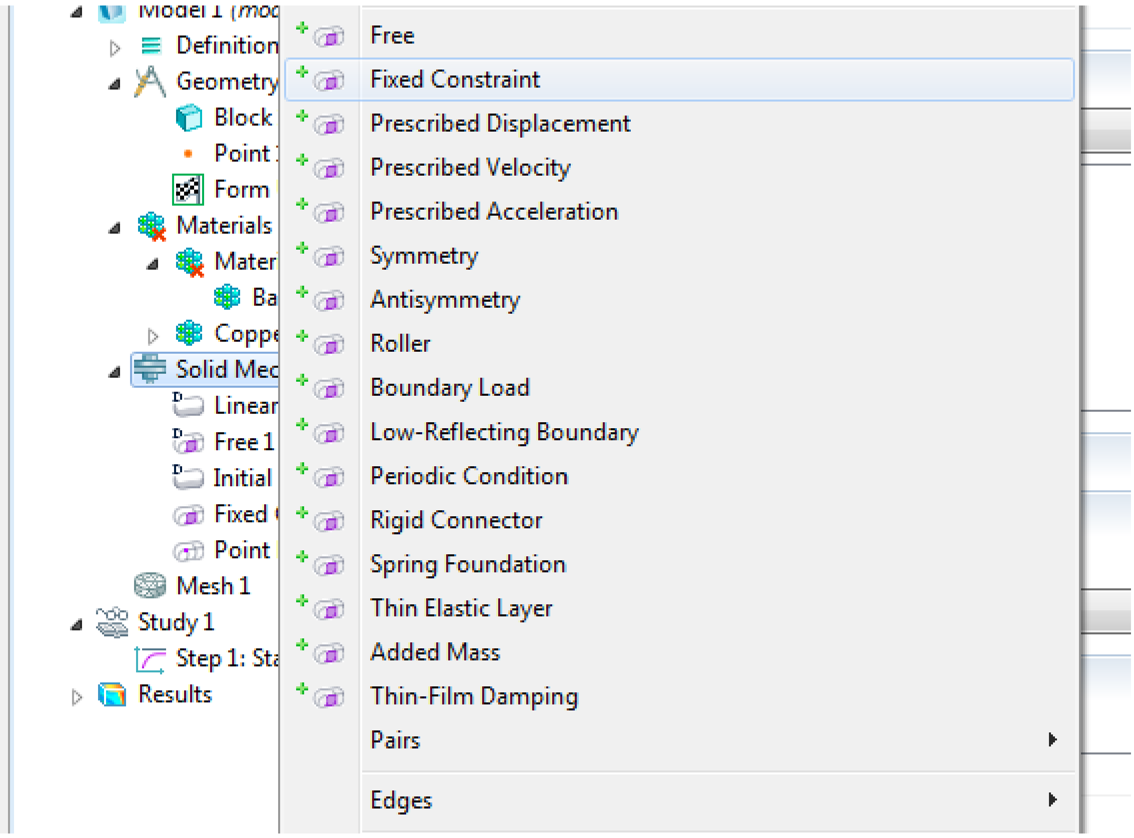

Type: Solid
Size and Shape
Width: 20 µm
Depth: 100 µm
Height: 5 µm
Position
Base: Corner
x: 0 µm
y: 0 µm
z: 0 µm
Axis
Axis type: Cartesian
x: 0
y: 0
z: 1
Rotation Angle


Point
x: 10 µm
y: 1 µm
z: 5 µm
Selections of Resulting Entities
Create selections

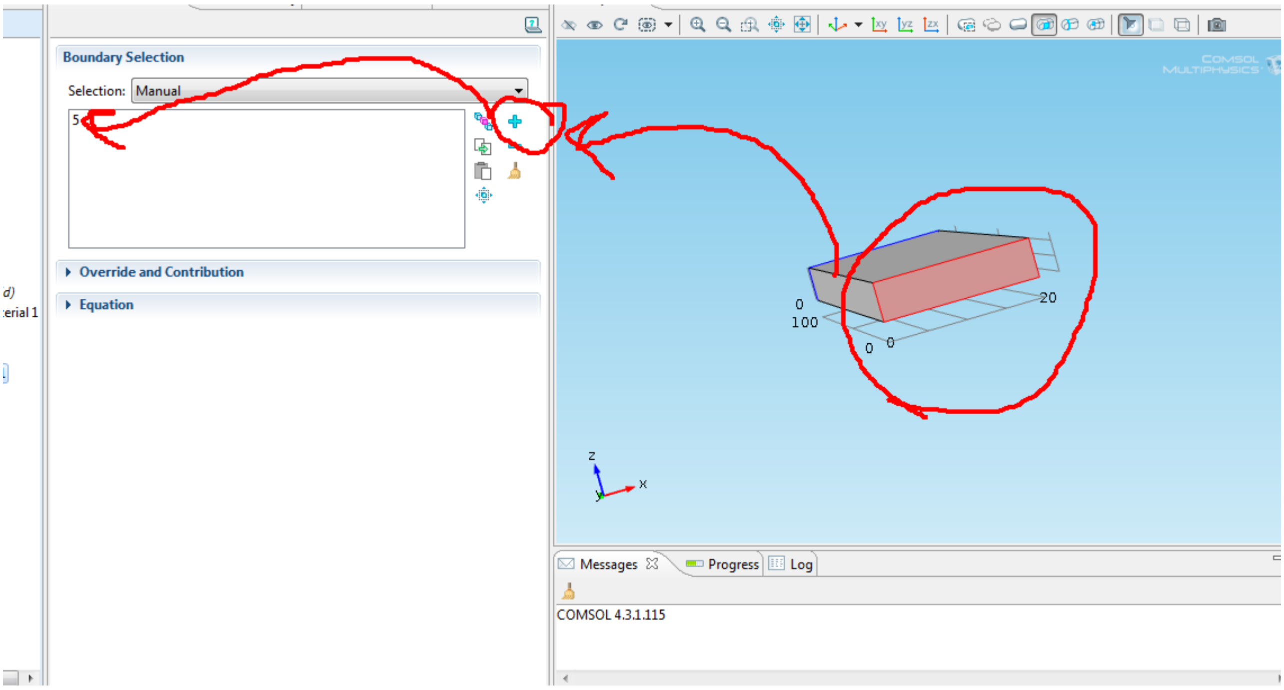

Finalization method:
Form a union
Relative repair tolerance:
1.0E-6

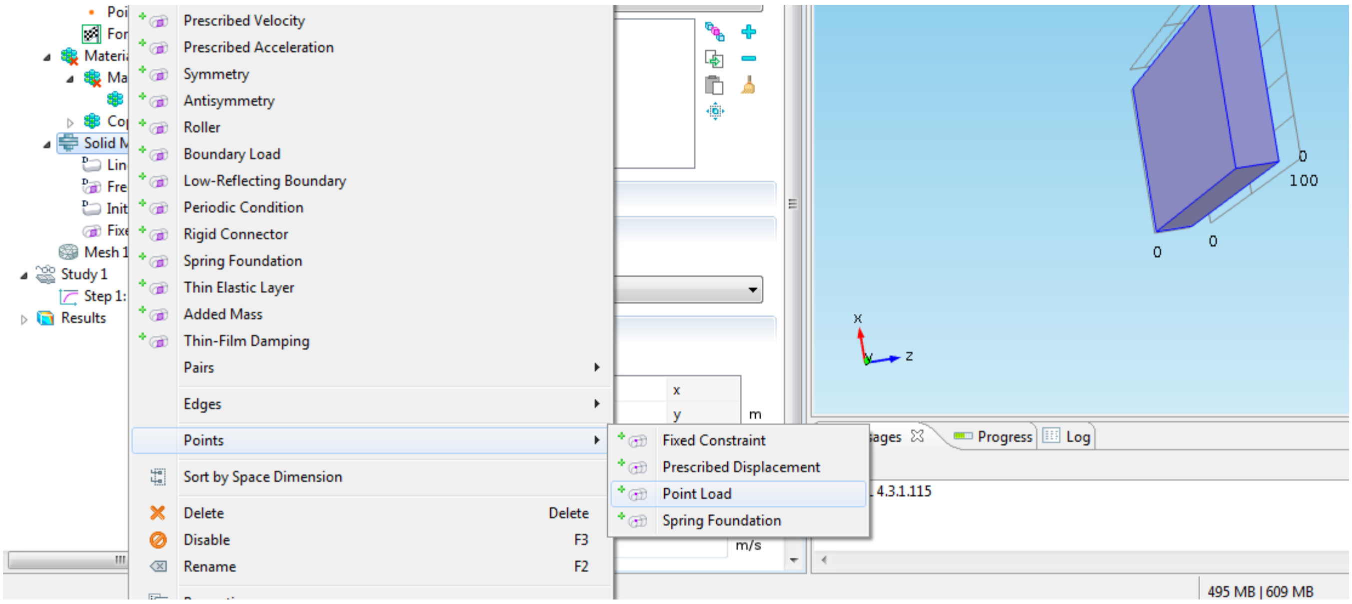


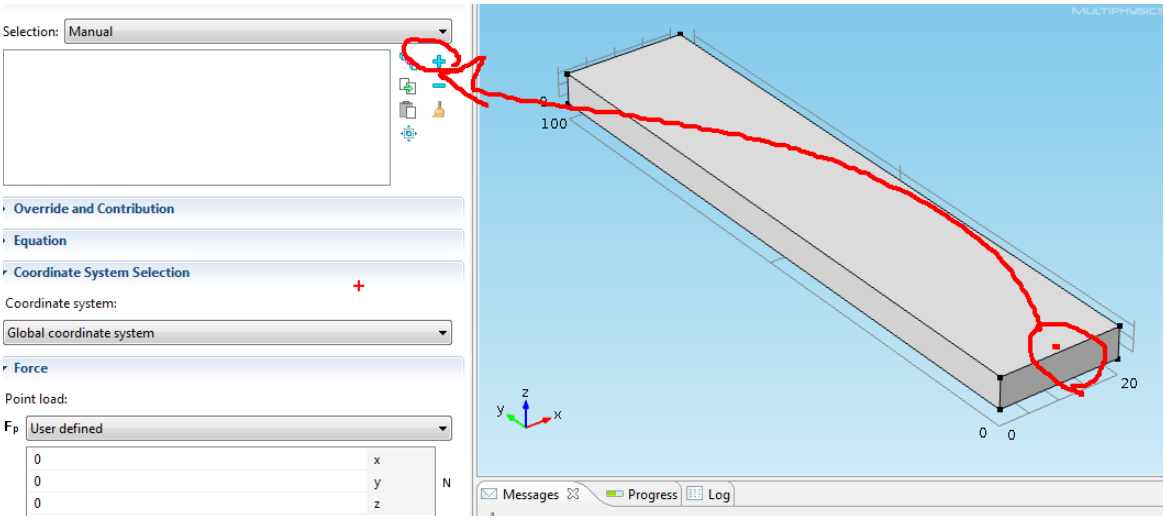


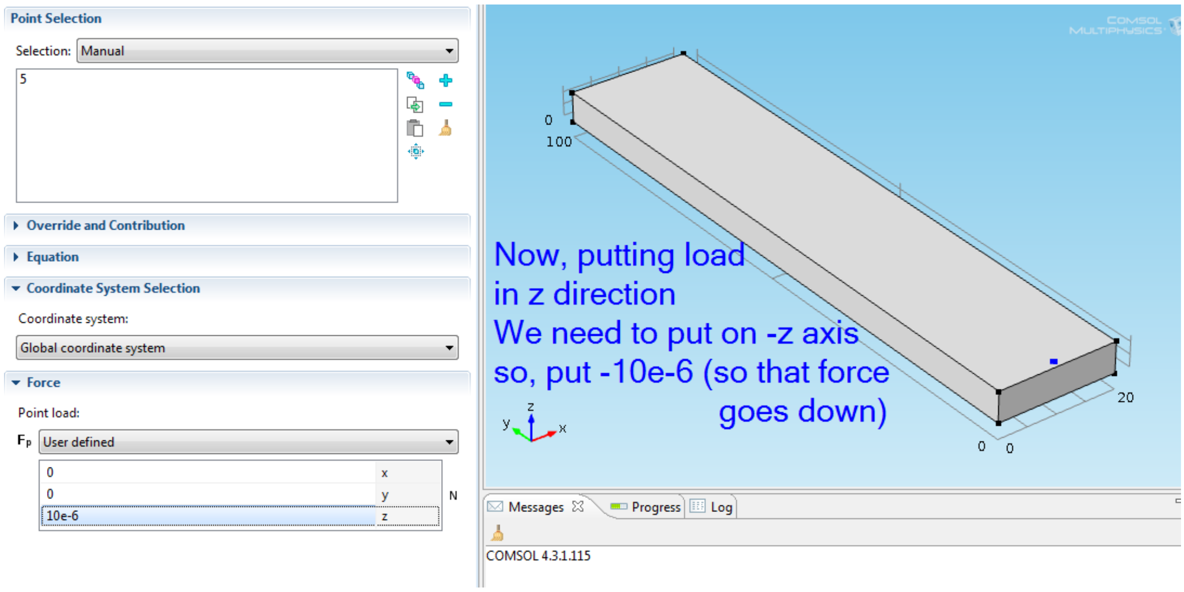


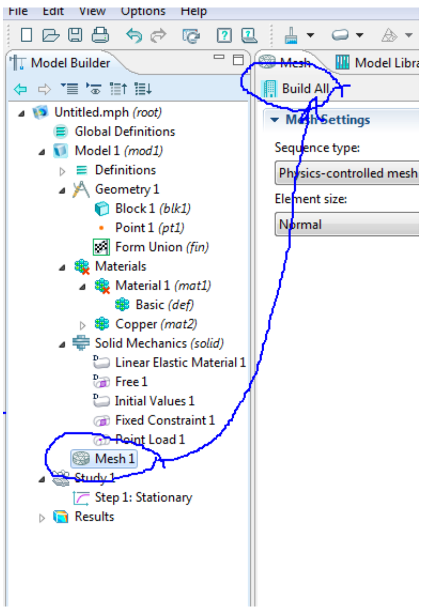
Now, rotate the model and select one of the sides of length 5. Next, click on + button on the toolbox at the side.

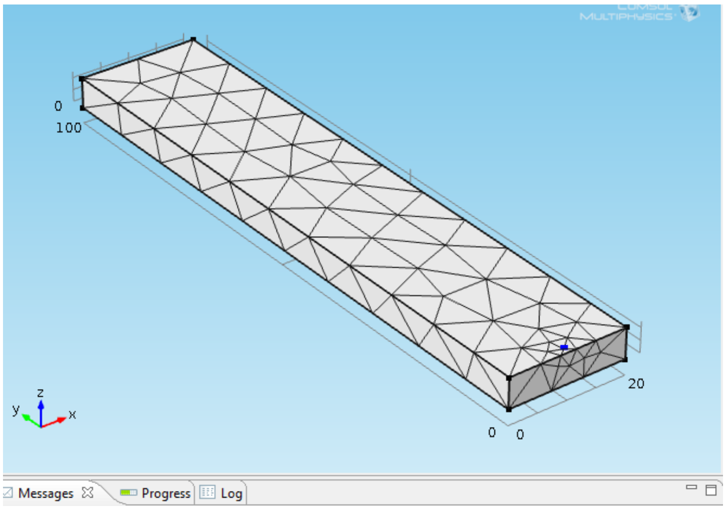

Boundary Selection
Selection: Manual
5
Override and Contribution
Equation
Messages
Progress
Log
COMSOL 4.3.1.115

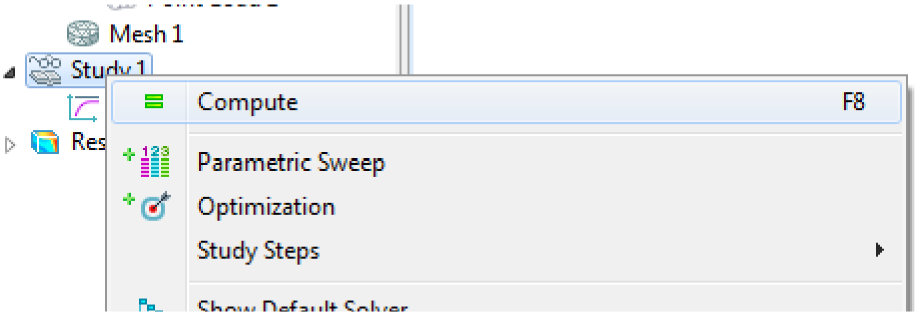

Prescribed Velocity
Prescribed Acceleration
Symmetry
Antisymmetry
Roller
Boundary Load
Low-Reflecting Boundary
Periodic Condition
Rigid Connector
Spring Foundation
Thin Elastic Layer
Added Mass
Thin-Film Damping
Pairs
Edges
Points
Sort by Space Dimension
Delete Delete
Disable F3
Rename F2
Fixed Constraint
Prescribed Displacement
Point Load
Spring Foundation
Study 1
Results
Progress
Log
495 MB | 609 MB

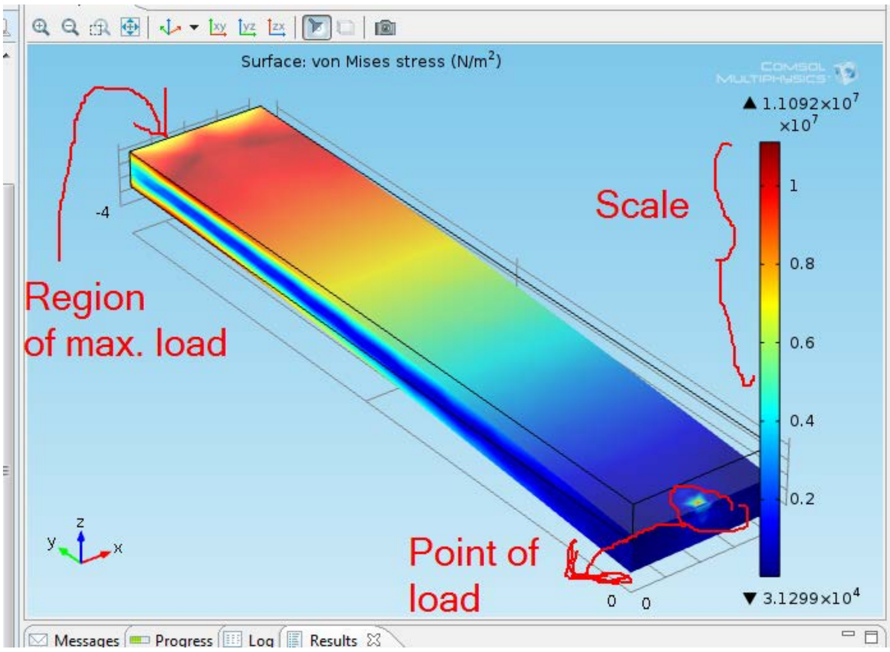

Selection: Manual
Override and Contribution
Equation
Coordinate System Selection
Coordinate system:
Global coordinate system
Force
Point load:
User defined
Messages
Progress
Log


Point Selection
Selection: Manual
5
Override and Contribution
Equation
Coordinate System Selection
Coordinate system:
Global coordinate system
Force
Point load:
User defined
10e-6
Now, putting load
in z direction
We need to put on -z axis
so, put -10e-6 (so that force
goes down)
Messages
Progress
Log
COMSOL 4.3.1.115

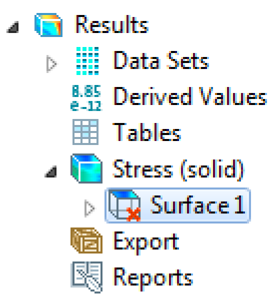

File Edit View Options Help
Model Builder
Untitled.mph (root)
Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Point 1 (pt1)
Form Union (fin)
Materials
Material 1 (mat1)
Basic (def)
Copper (mat2)
Solid Mechanics (solid)
Linear Elastic Material 1
Free 1
Initial Values 1
Fixed Constraint 1
Point Load 1
Mesh 1
Study 1
Step 1: Stationary
Results
Mesh
Build All
Mesh Settings
Sequence type:
Physics-controlled mesh
Element size:
Normal

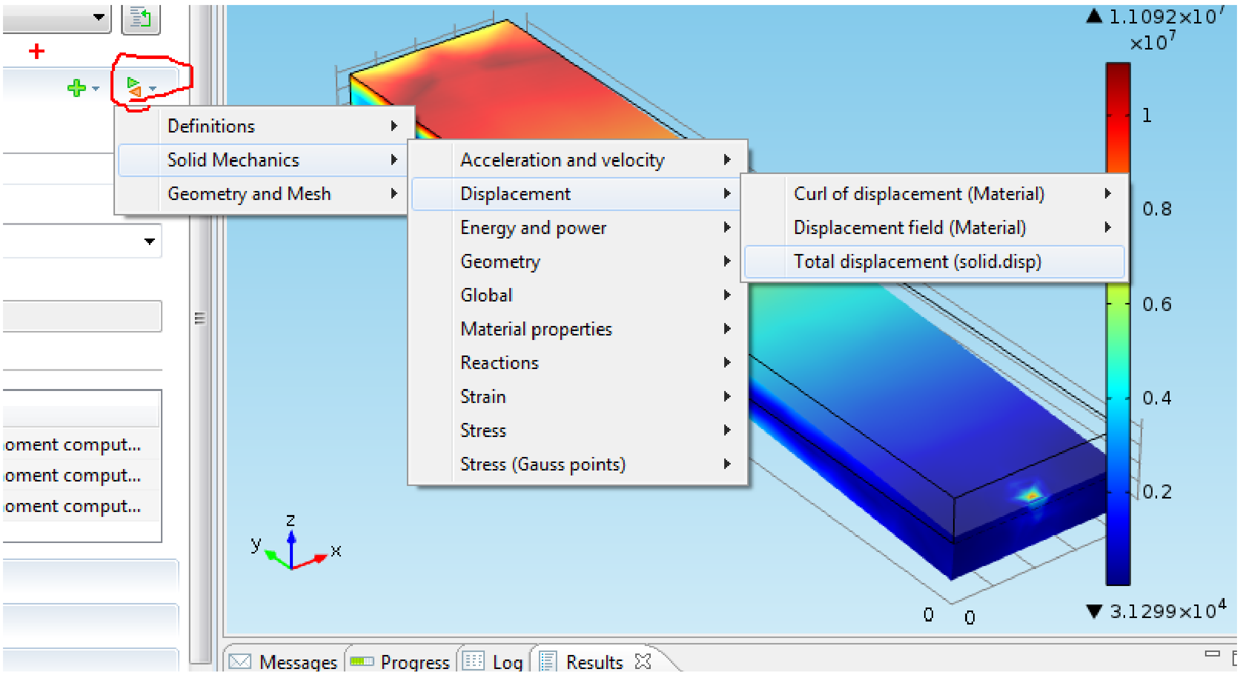




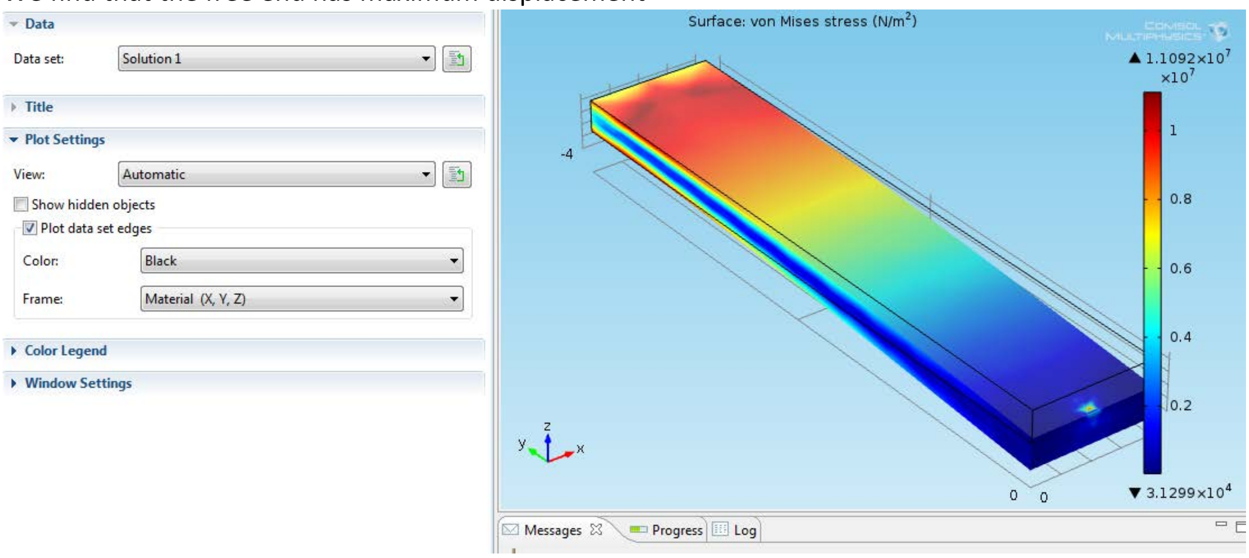


This makes the diagram colored
A strip tells the amount of stress and the details on that.
Which figure has the max stress - we get to know from the figure

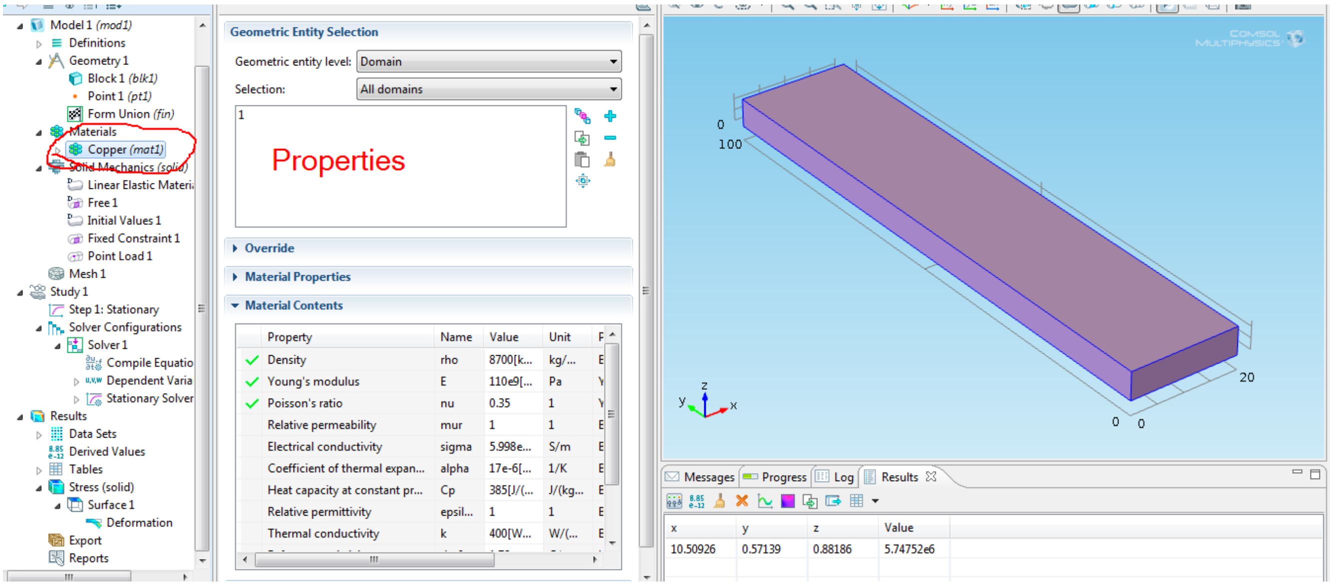




We find that the free end has maximum displacement

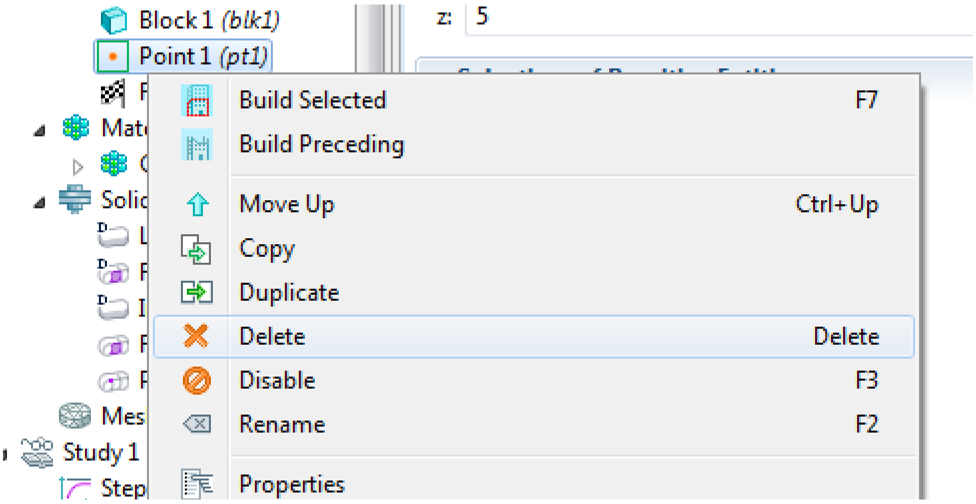


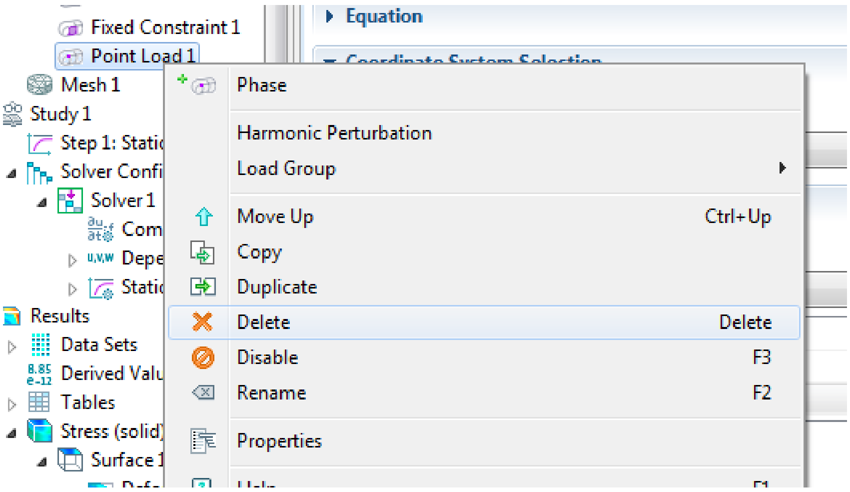
Note:
We can know the properties of material we are using. Here we are using copper. So, click on it to see its properties.

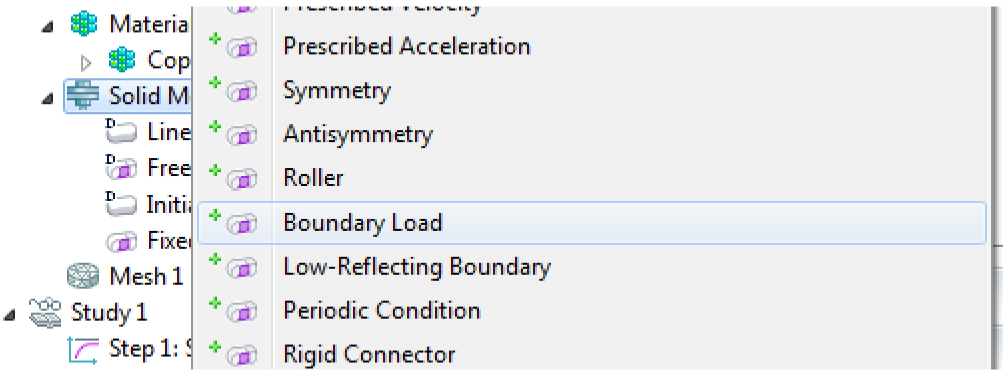


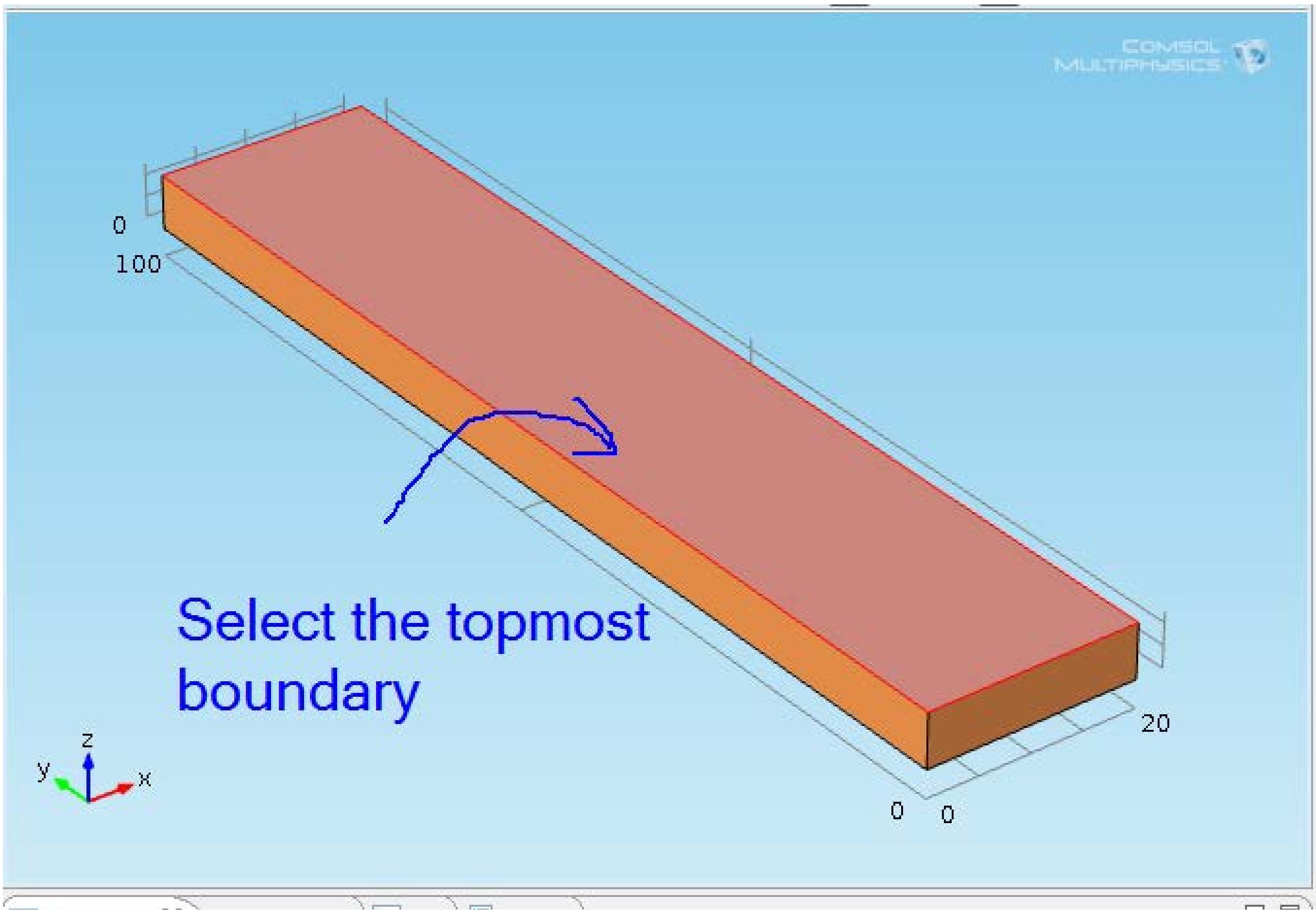
Save the file.

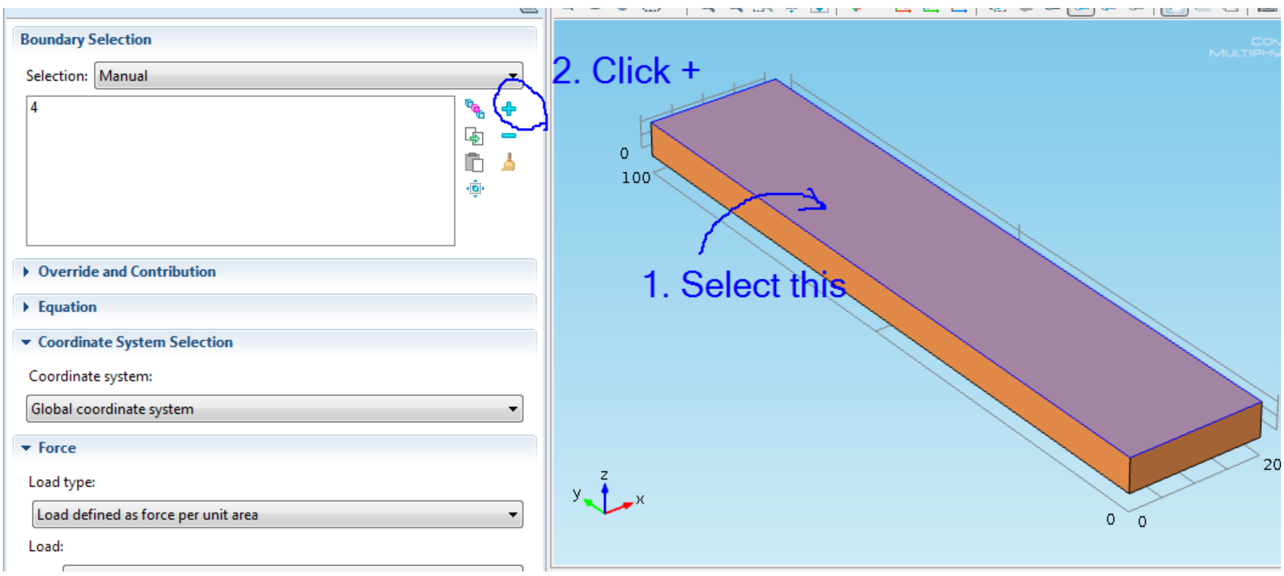
Boundary LOAD

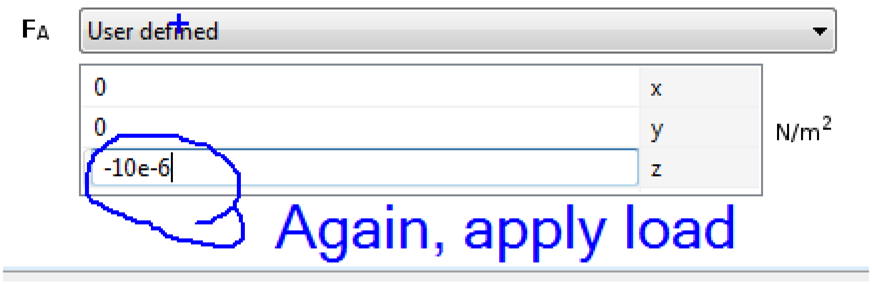


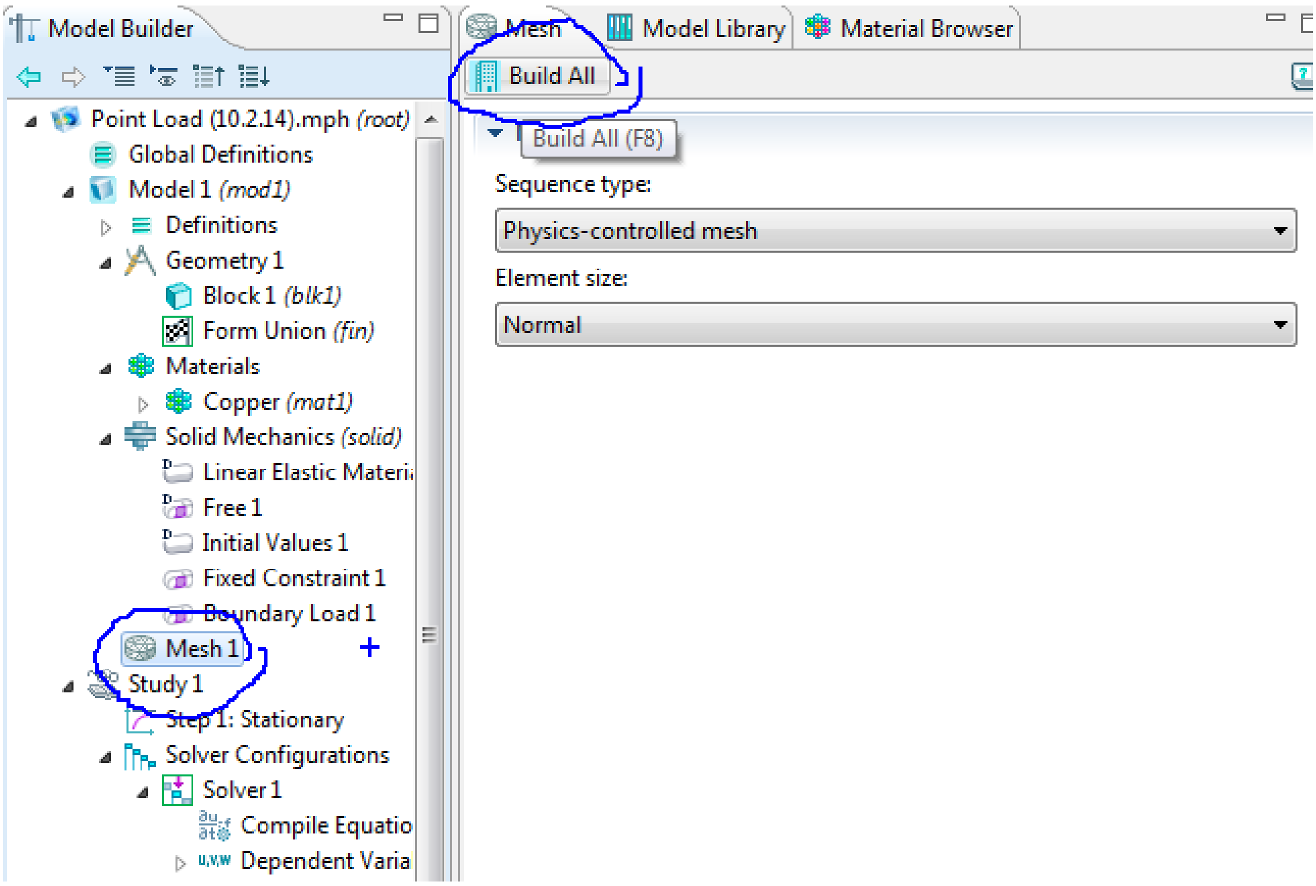


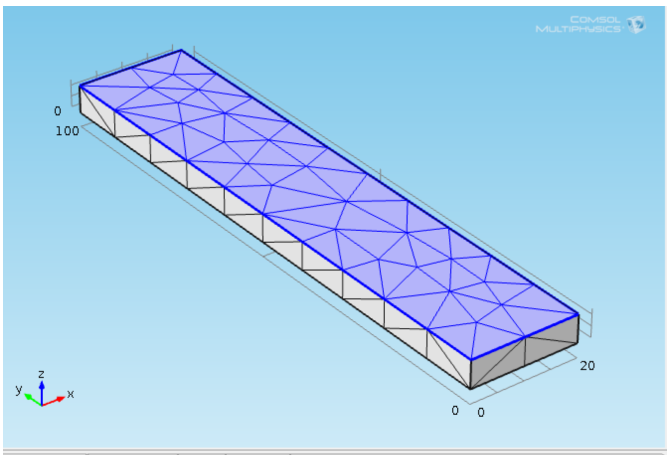


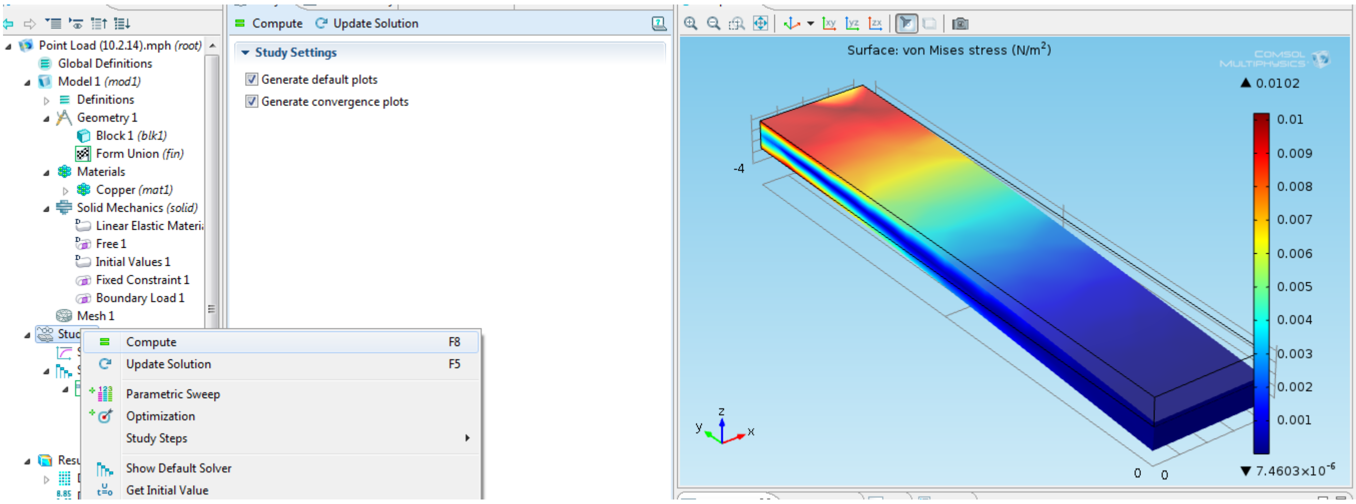

Select the topmost boundary

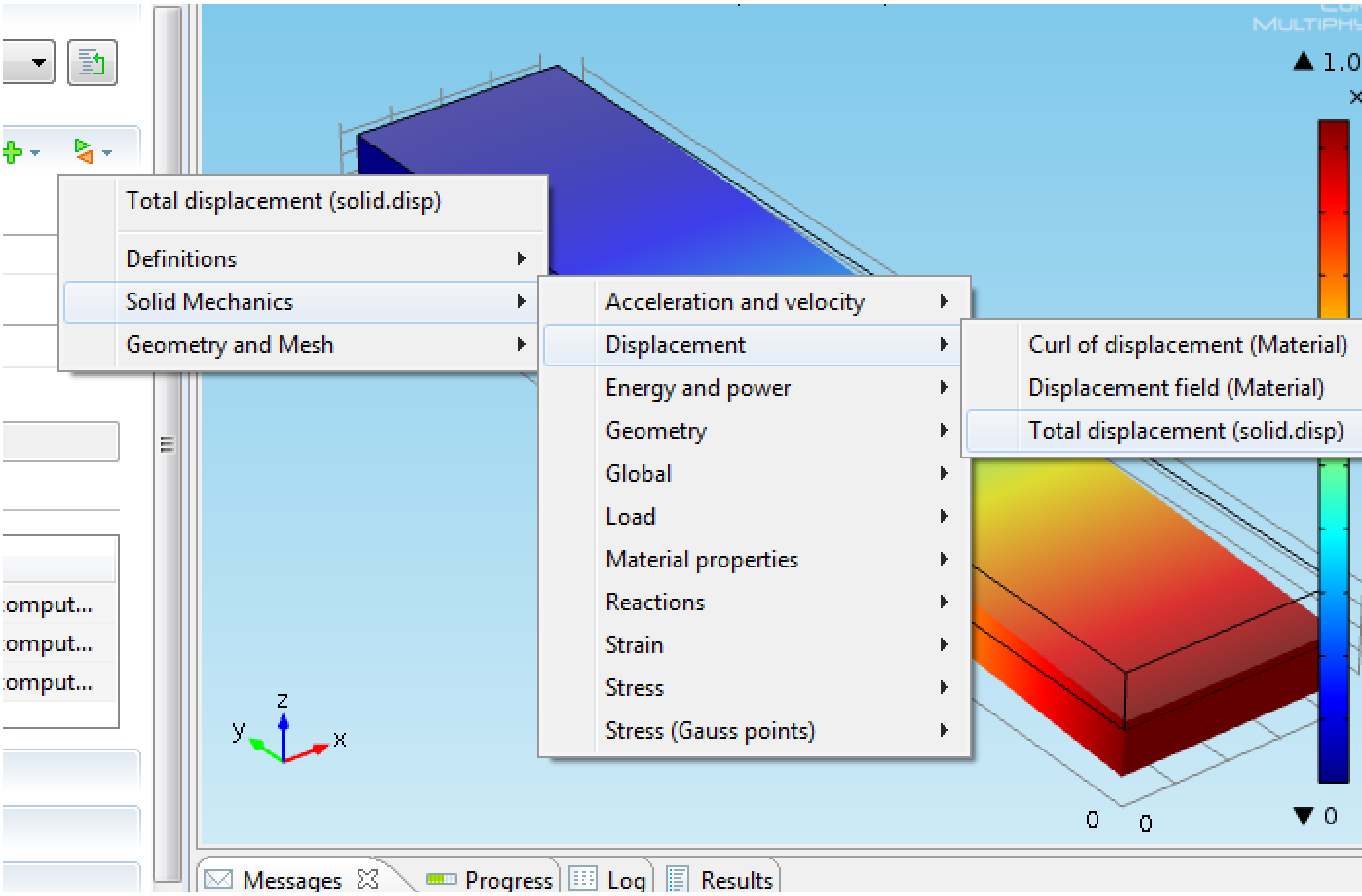

Boundary Selection
Selection: Manual
4
Override and Contribution
Equation
Coordinate System Selection
Coordinate system:
Global coordinate system
Force
Load type:
Load defined as force per unit area
Load:
2. Click +
1. Select this

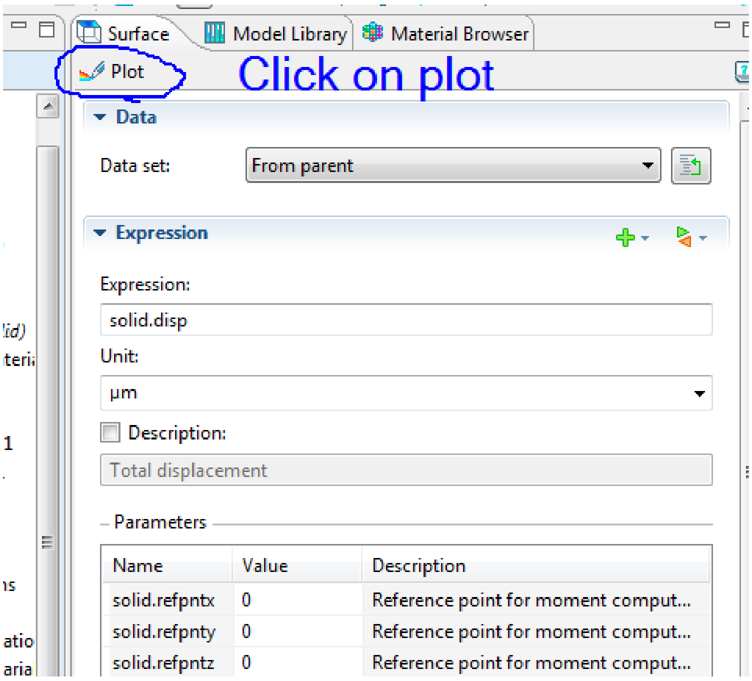

FA
User defined
0 x
0 y
-10e-6 z
N/m2
Again, apply load

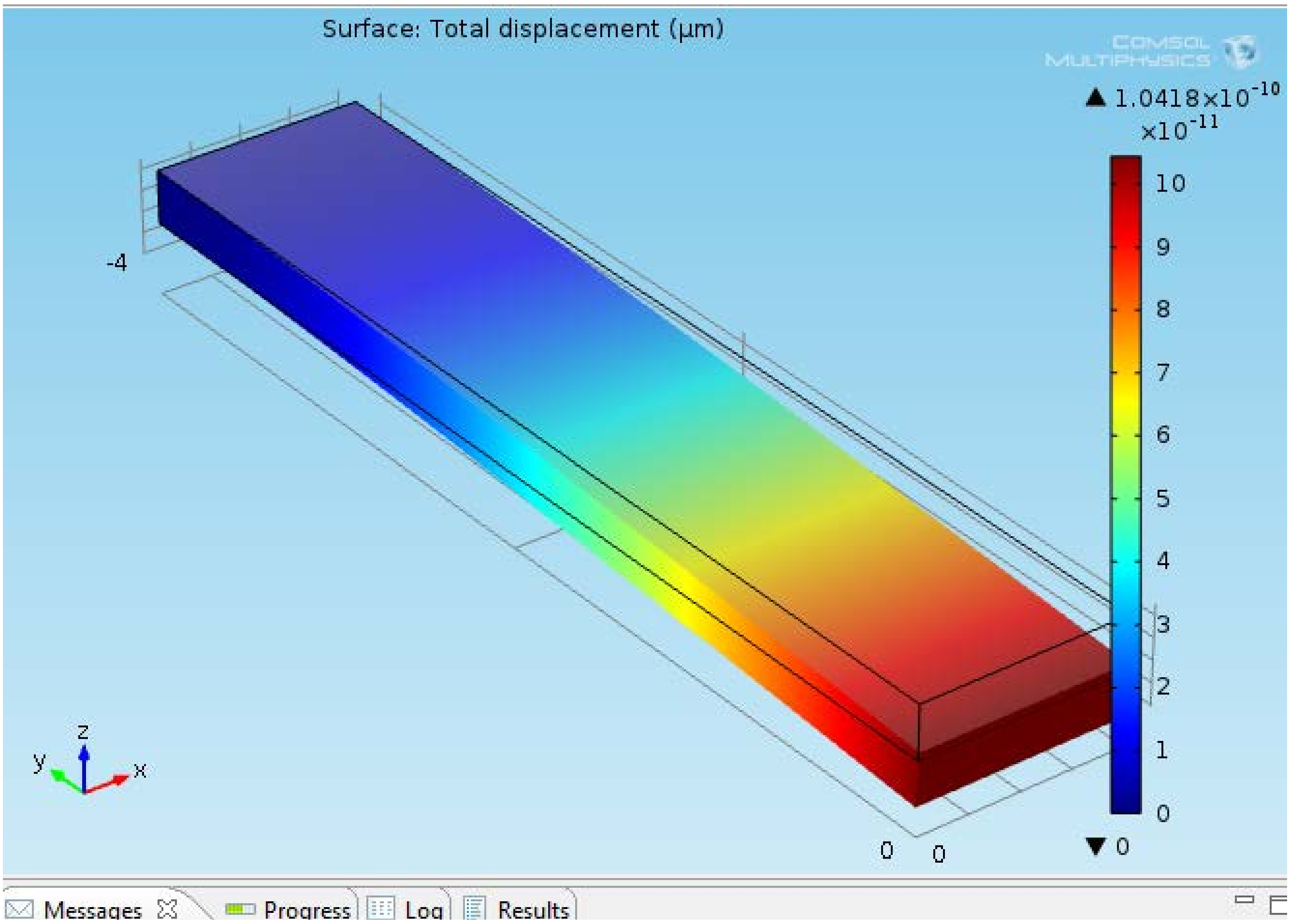

Model Builder
Point Load (10.2.14).mph (root)
Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Form Union (fin)
Materials
Copper (mat1)
Solid Mechanics (solid)
Linear Elastic Materi
Free 1
Initial Values 1
Fixed Constraint 1
Boundary Load 1
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Solver 1
Compile Equatio
Dependent Varia
Mesh
Model Library
Material Browser
Build All
Build All (F8)
Sequence type:
Physics-controlled mesh
Element size:
Normal


0
100
20
0
0


Point Load (10.2.14).mph (root)
Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Form Union (fin)
Materials
Copper (mat1)
Solid Mechanics (solid)
Linear Elastic Materi
Free 1
Initial Values 1
Fixed Constraint 1
Boundary Load 1
Mesh 1
Compute F8
Update Solution F5
Parametric Sweep
Optimization
Study Steps
Show Default Solver
Get Initial Value
Compute
Update Solution
Study Settings
Generate default plots
Generate convergence plots
Surface: von Mises stress (N/m²)
0.0102
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
7.4603×10⁻⁶


Total displacement (solid.disp)
Definitions
Solid Mechanics
Geometry and Mesh
Acceleration and velocity
Displacement
Energy and power
Geometry
Global
Load
Material properties
Reactions
Strain
Stress
Stress (Gauss points)
Curl of displacement (Material)
Displacement field (Material)
Total displacement (solid.disp)
Messages
Progress
Log
Results

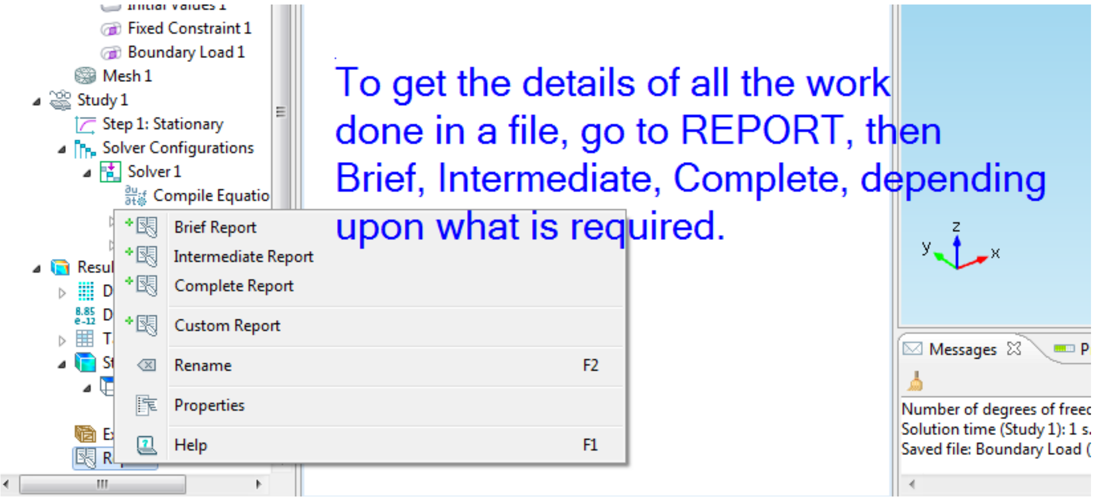


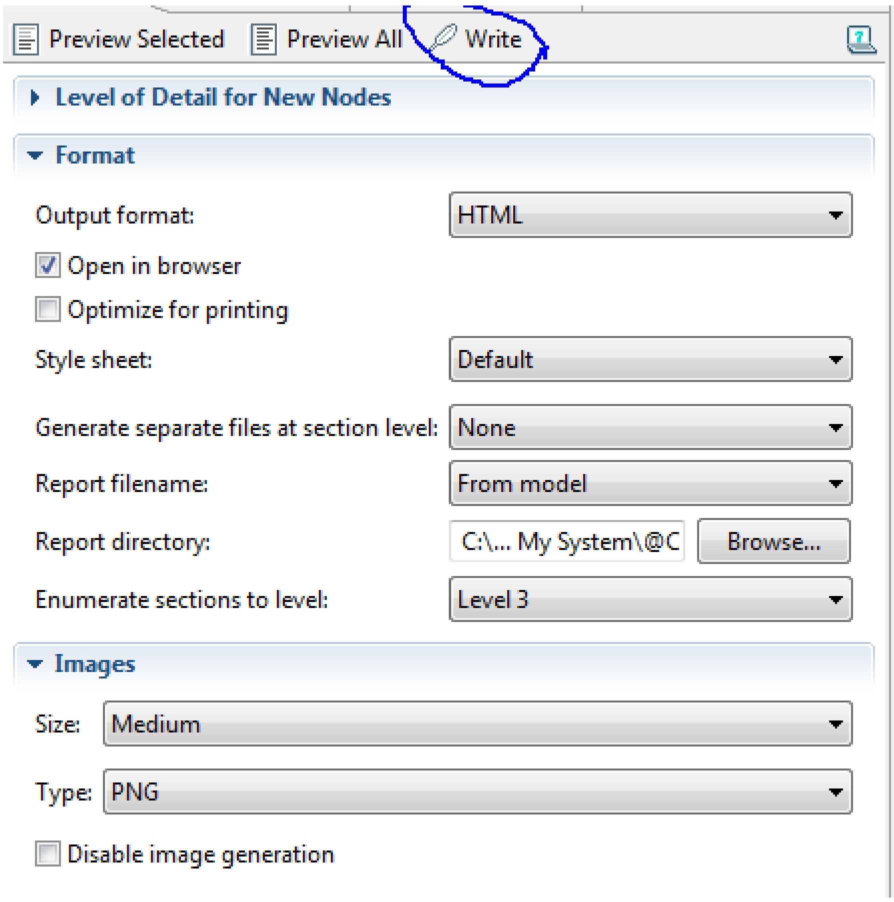


The total displacement is, as shown in the diagram.

By observation, it is lesser, as compared to point load.

Save the file again.



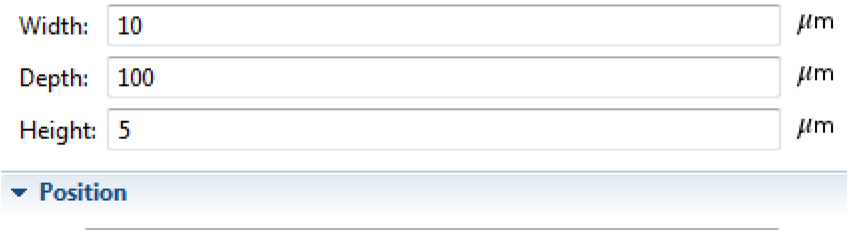


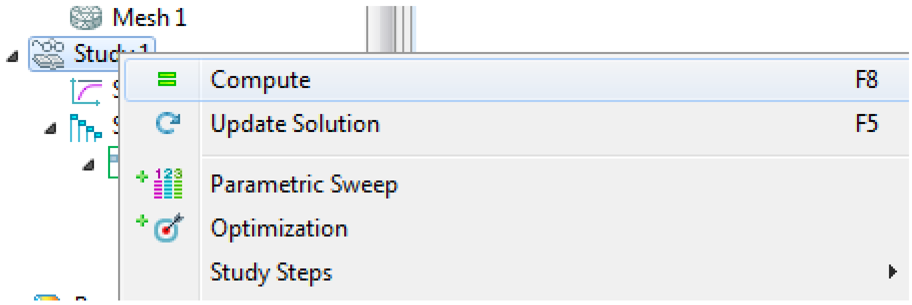
Changes

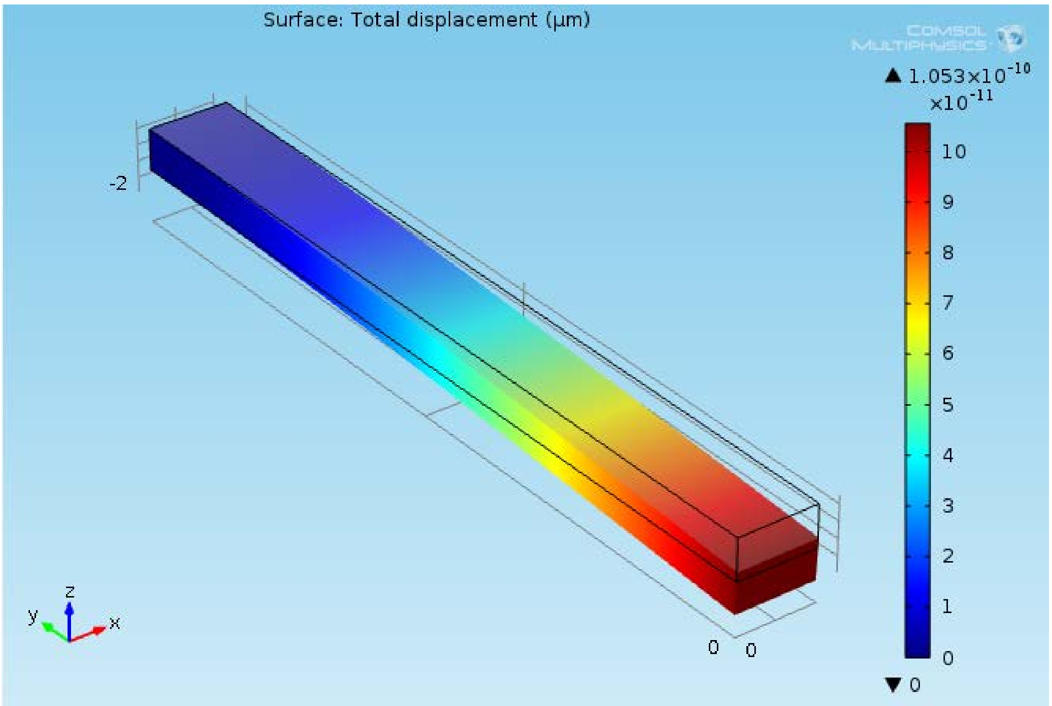
Now,

Change 1

Changing the values in geometry and seeing the deflection in that case.

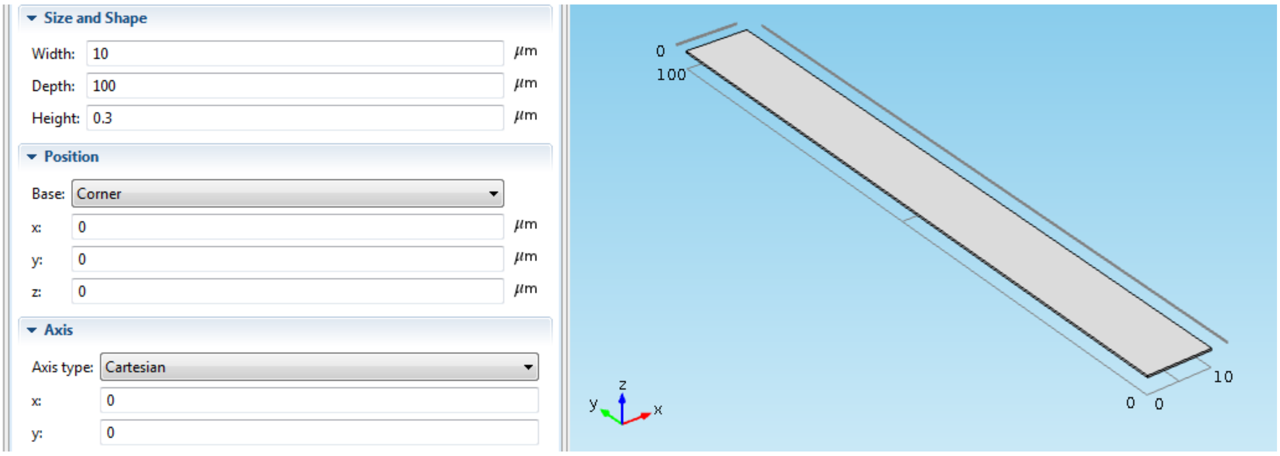


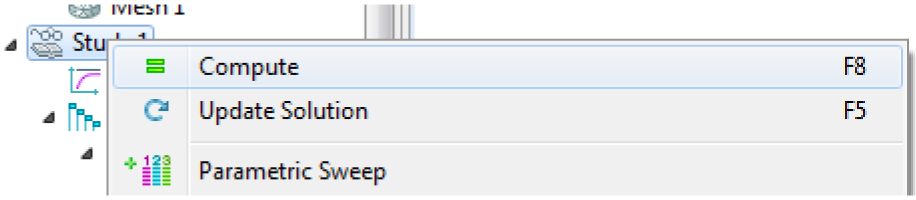


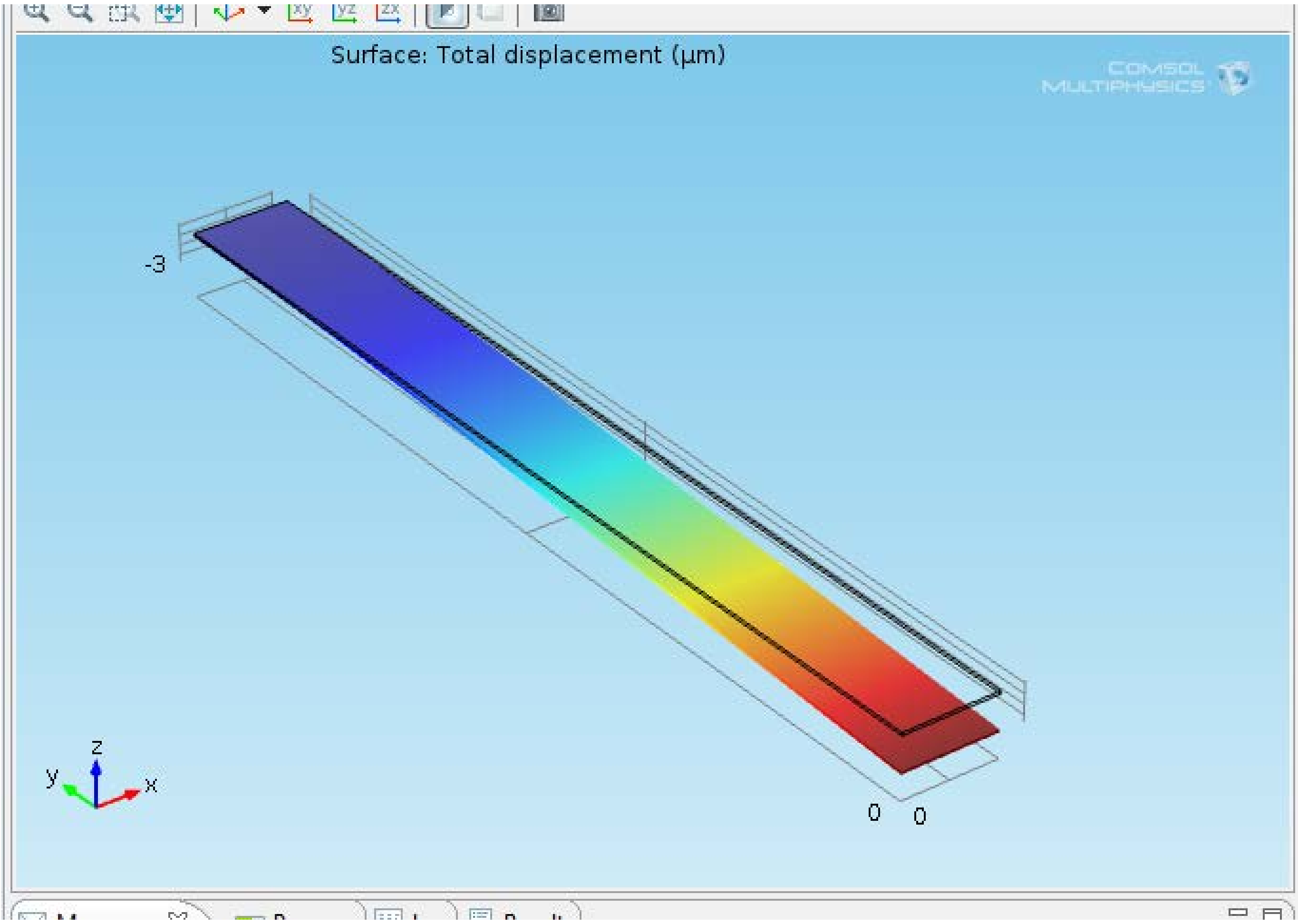


Change 2

Now, change the thickness (height) of the model and for small values, check which is the smallest value, giving the maximum deflection and is able to tolerate as well.

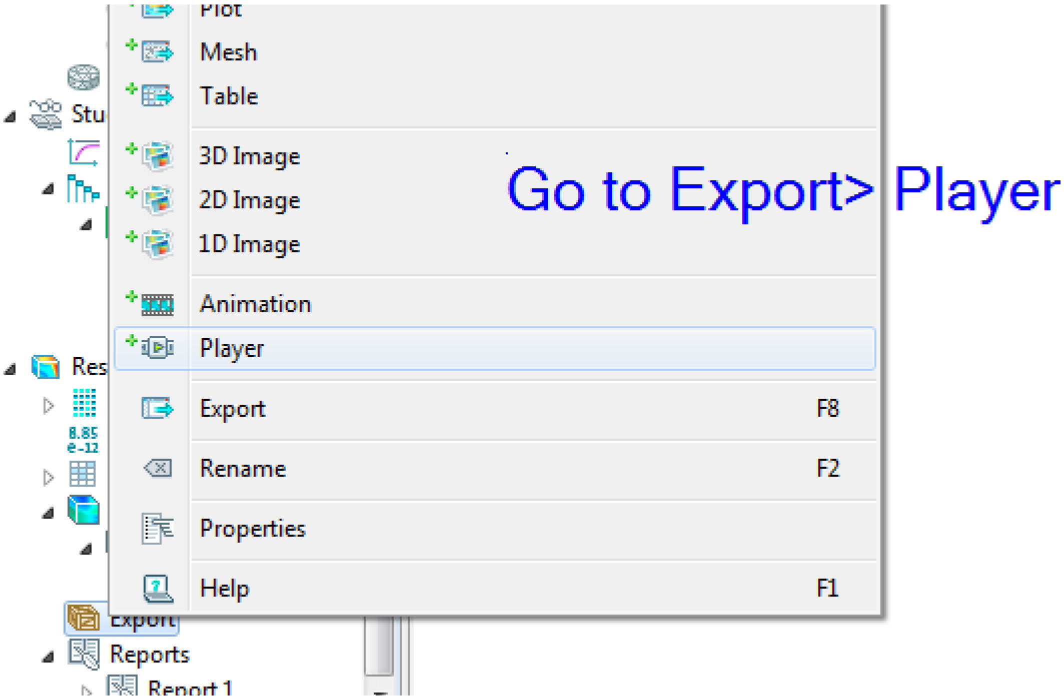






EXTRA

Displaying moving details of how the figure was getting modified

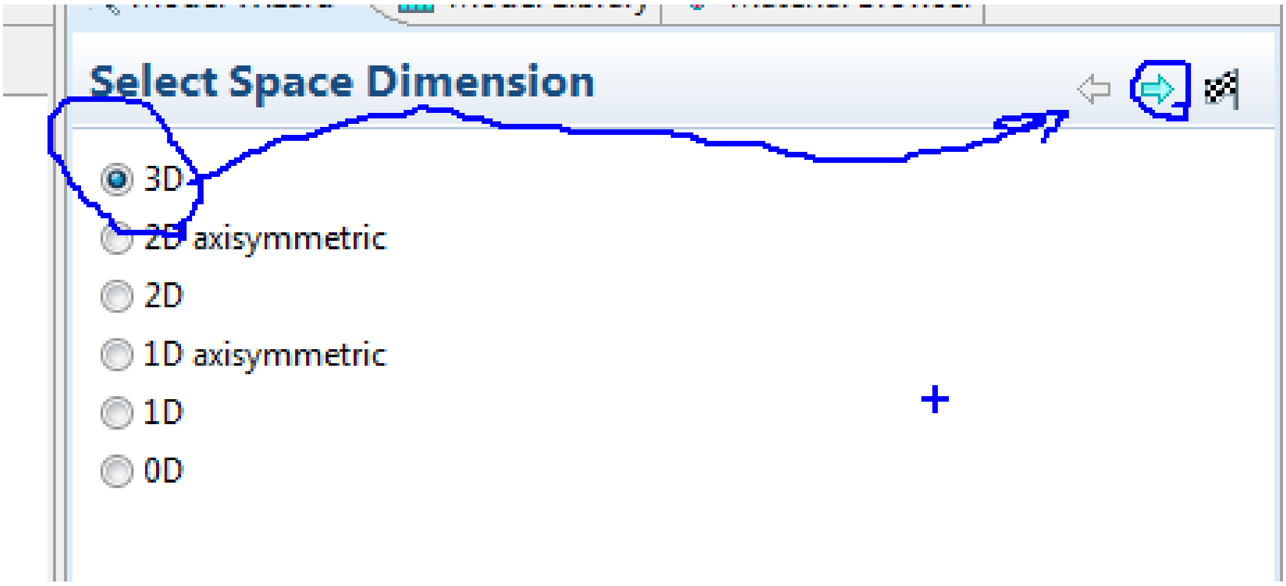


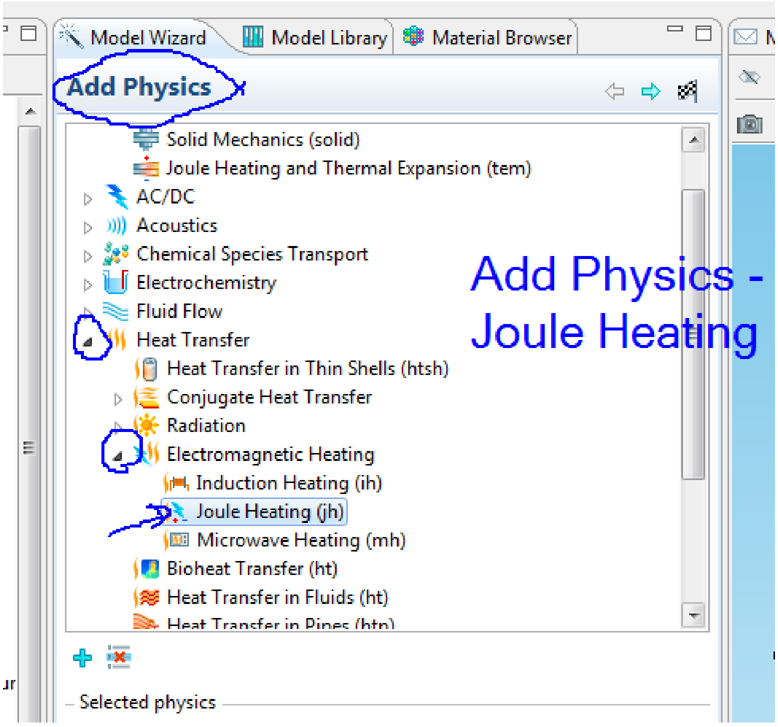
Joule Heating Method for Actuator

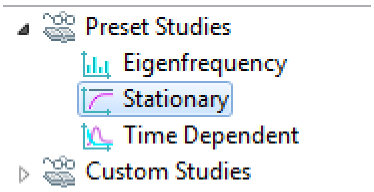
We want to see how the temperature varies in our work piece when it is made as per the specifications.

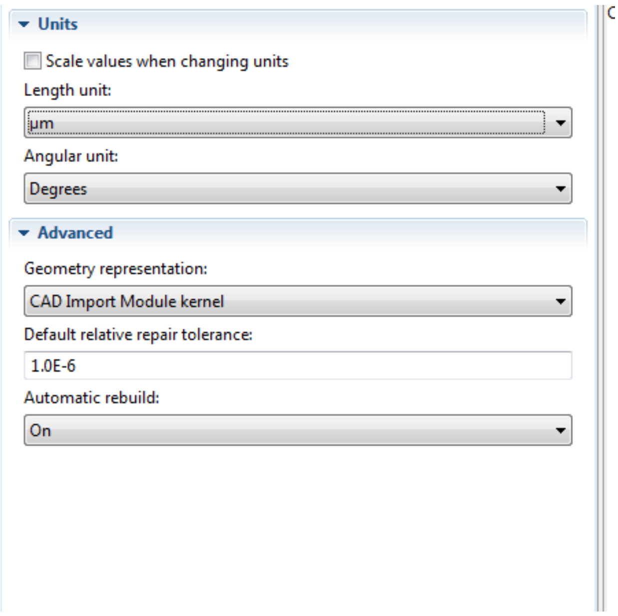
Idea :
S1) Make a 3d Figure. For that, make a workplane under geometry tab. Then, add rectangles as per the dimension. Next, go to Work plane option and click on Extrude. That makes it 3D.
S2) Add Material. Go to Material library and select Poly-Si.
MEMS>Semiconductor>Poly-Si
S3) Select Joule Heating in Physics.
Model 1 - Right Click> Add Physics
Heat Transfer> Electromagnetic Heating> Joule Heating (jh)
S4) Now, start adding the properties to the work piece.
S5) Do meshing of the object
S6) Compute

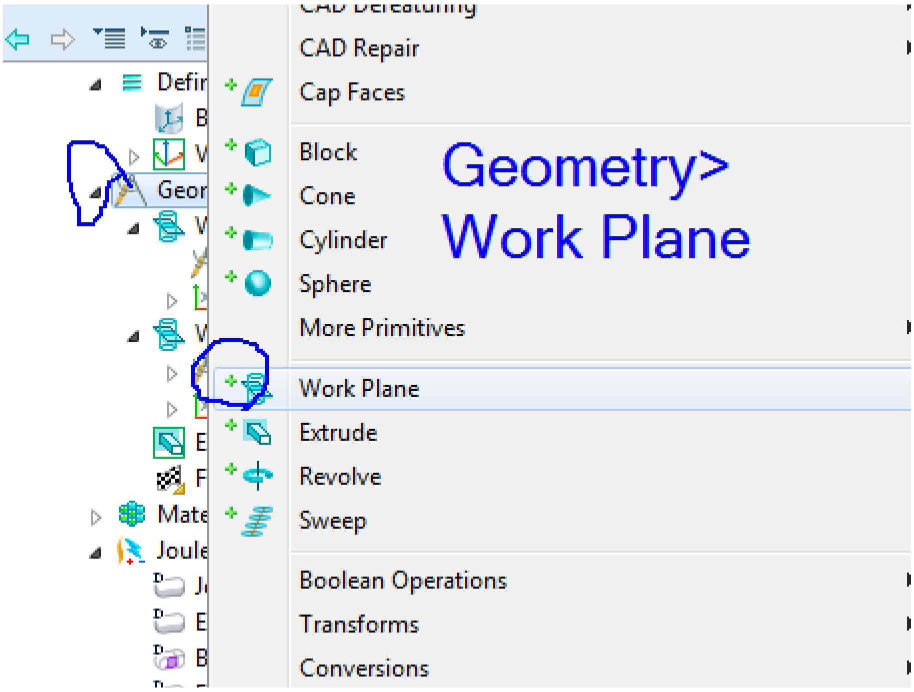
Objective - To model Joule heating of a micro actuator using COMSOL Joule heating module

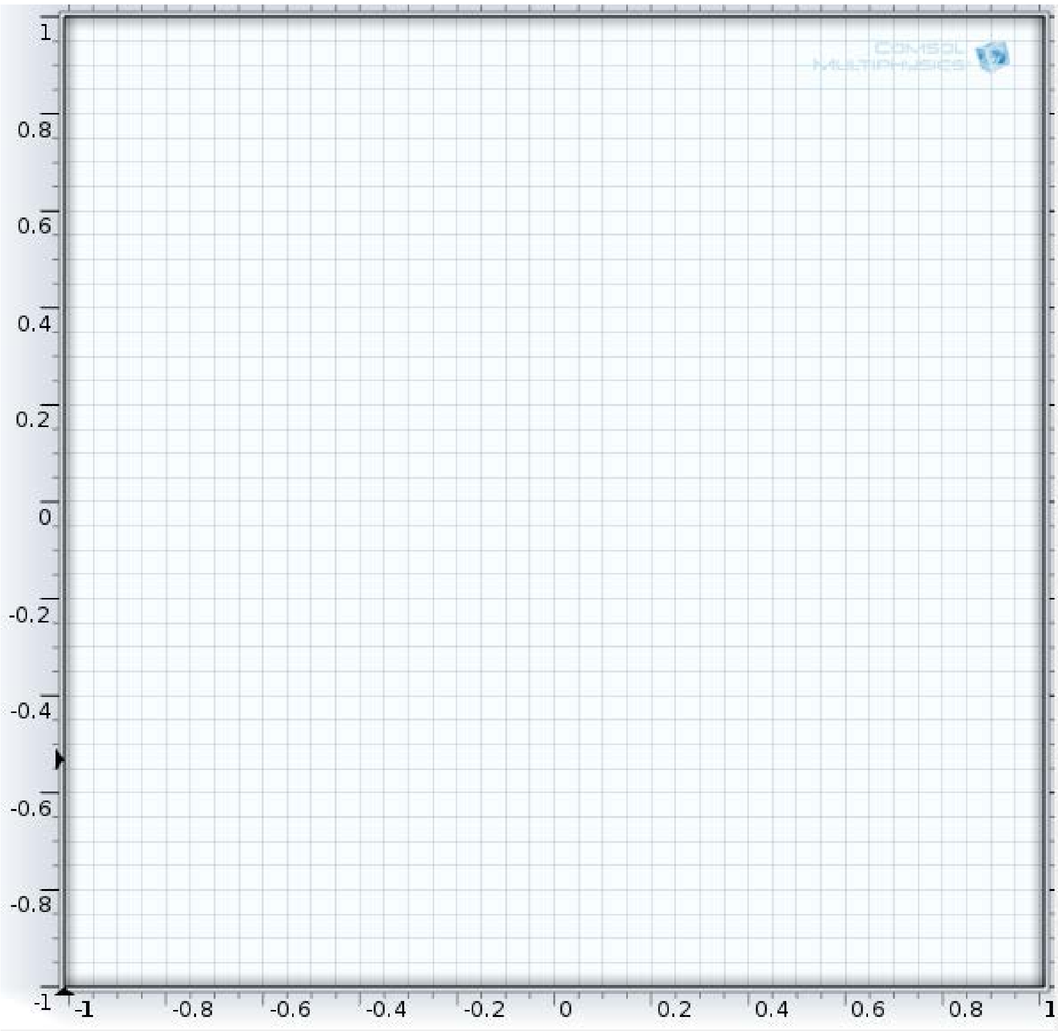


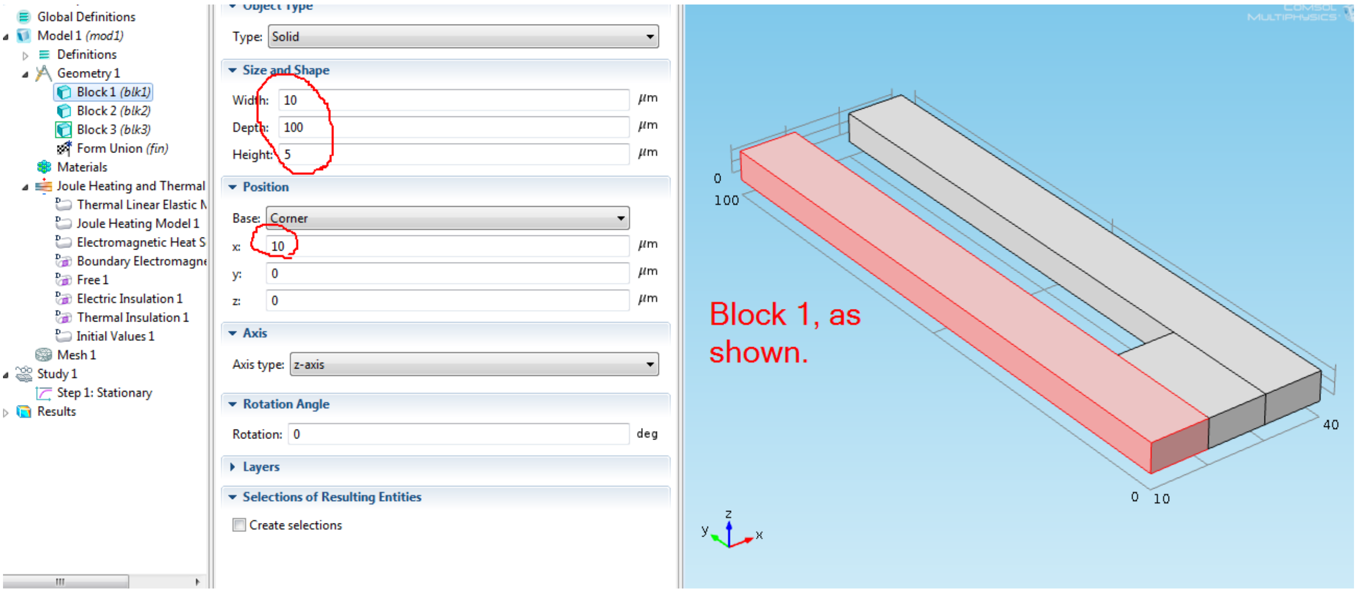

Model Wizard
Model Library
Material Browser
Add Physics
Solid Mechanics (solid)
Joule Heating and Thermal Expansion (tem)
AC/DC
Acoustics
Chemical Species Transport
Electrochemistry
Fluid Flow
Heat Transfer
Heat Transfer in Thin Shells (htsh)
Conjugate Heat Transfer
Radiation
Electromagnetic Heating
Induction Heating (ih)
Joule Heating (jh)
Microwave Heating (mh)
Bioheat Transfer (ht)
Heat Transfer in Fluids (ht)
Selected physics
Add Physics -
Joule Heating

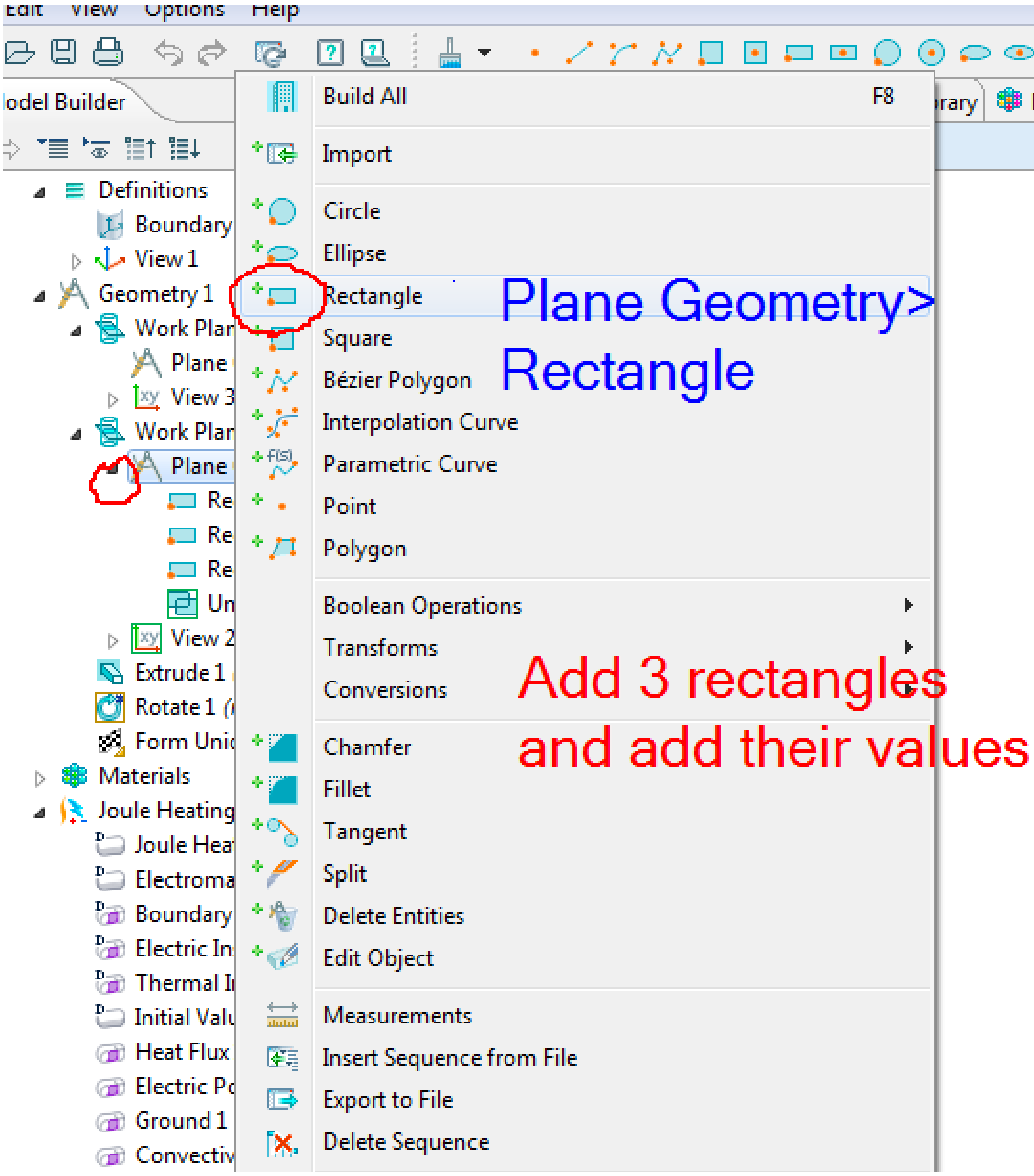

Preset Studies
Eigenfrequency
Stationary
Time Dependent
Custom Studies

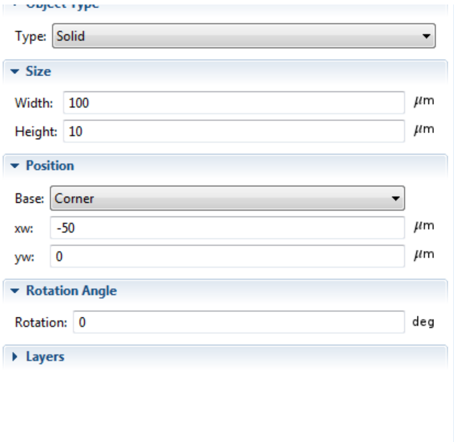

Units
Scale values when changing units
Length unit:
µm
Angular unit:
Degrees
Advanced
Geometry representation:
CAD Import Module kernel
Default relative repair tolerance:
1.0E-6
Automatic rebuild:
On

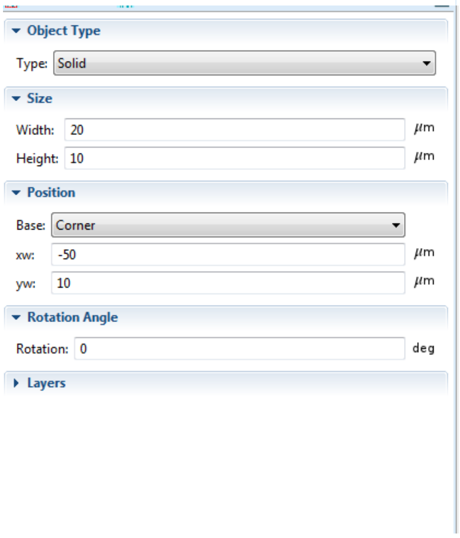

CAD Repair
Cap Faces
Block
Cone
Cylinder
Sphere
More Primitives
Work Plane
Extrude
Revolve
Sweep
Boolean Operations
Transforms
Conversions
Geometry>
Work Plane

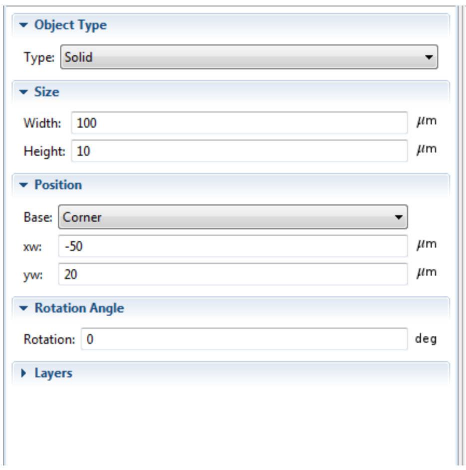


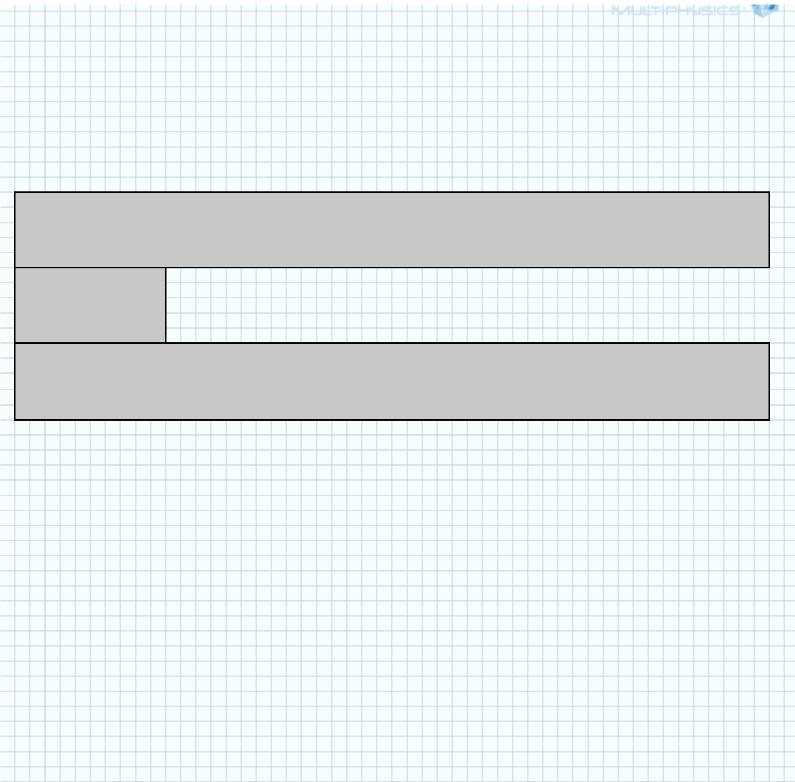

Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Block 2 (blk2)
Block 3 (blk3)
Form Union (fin)
Materials
Joule Heating and Thermal
Thermal Linear Elastic
Joule Heating Model 1
Electromagnetic Heat
Boundary Electromagne
Free 1
Electric Insulation 1
Thermal Insulation 1
Initial Values 1
Mesh 1
Study 1
Step 1: Stationary
Results
Object Type
Type: Solid
Size and Shape
Width: 10 µm
Depth: 100 µm
Height: 5 µm
Position
Base: Corner
x: 10 µm
y: 0 µm
z: 0 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities
Create selections
Block 1, as shown.


Edit View Options Help
Model Builder
Material Brow
Definitions
Boundary
View 1
Geometry 1
Work Plan
Plane
View 3
Extrude 1
Rotate 1
Form Unio
Materials
Joule Heating
Build All F8
Import
Circle
Ellipse
Rectangle
Square
Bézier Polygon
Interpolation Curve
Parametric Curve
Point
Polygon
Boolean Operations
Transforms
Conversions
Chamfer
Fillet
Tangent
Split
Delete Entities
Edit Object
Measurements
Insert Sequence from File
Export to File
Delete Sequence
Plane Geometry>
Rectangle
Add 3 rectangles
and add their values

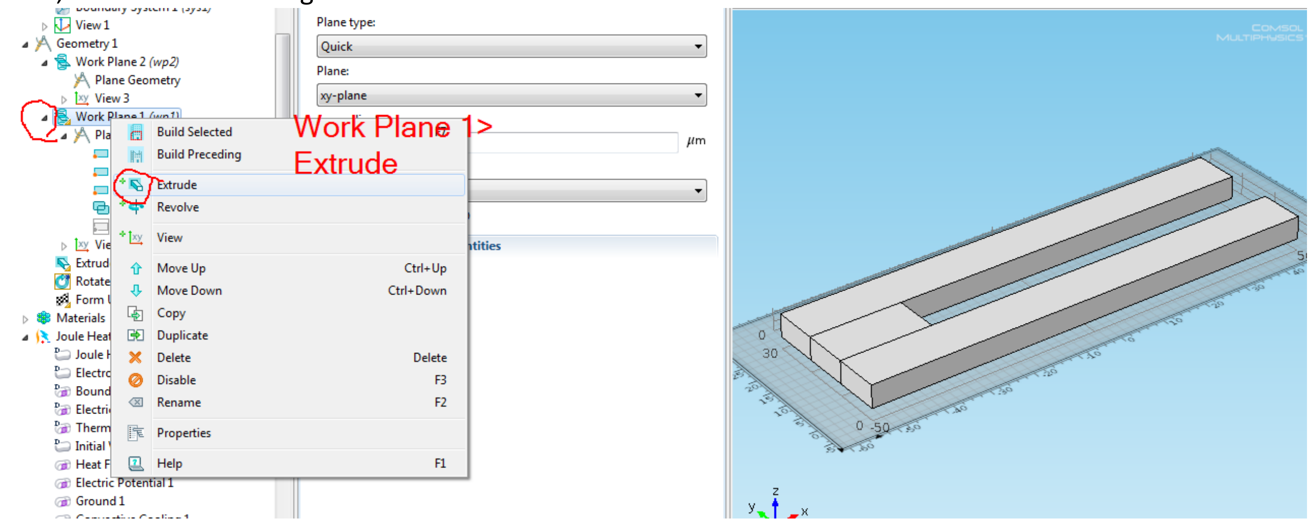

Type: Solid
Size
Width: 100 µm
Height: 10 µm
Position
Base: Corner
xw: -50 µm
yw: 0 µm
Rotation Angle
Rotation: 0 deg
Layers

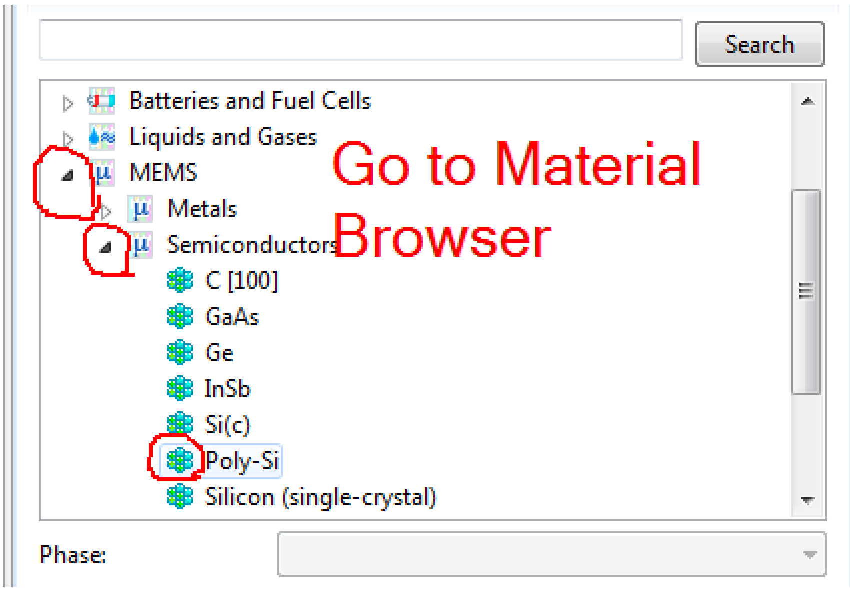

Object Type
Type: Solid
Size
Width: 20 µm
Height: 10 µm
Position
Base: Corner
xw: -50 µm
yw: 10 µm
Rotation Angle
Rotation: 0 deg
Layers

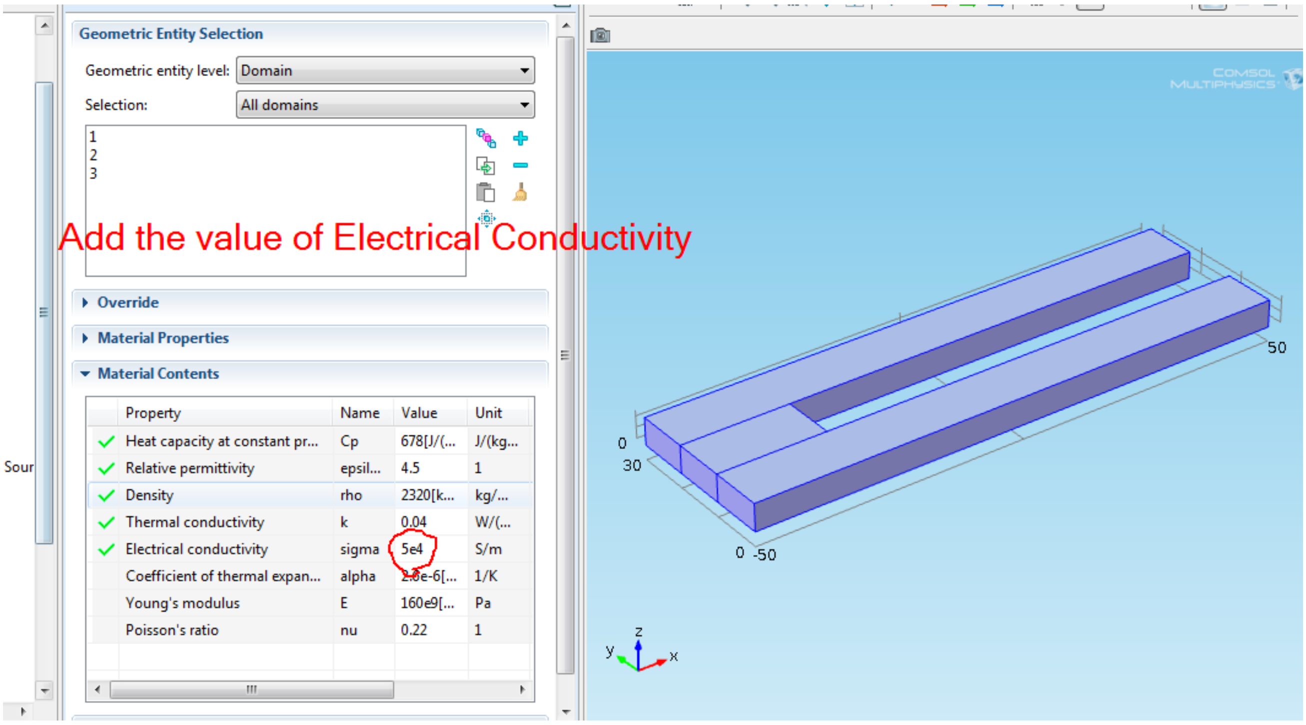

Object Type
Type: Solid
Size
Width: 100 µm
Height: 10 µm
Position
Base: Corner
xw: -50 µm
yw: 20 µm
Rotation Angle
Rotation: 0 deg
Layers

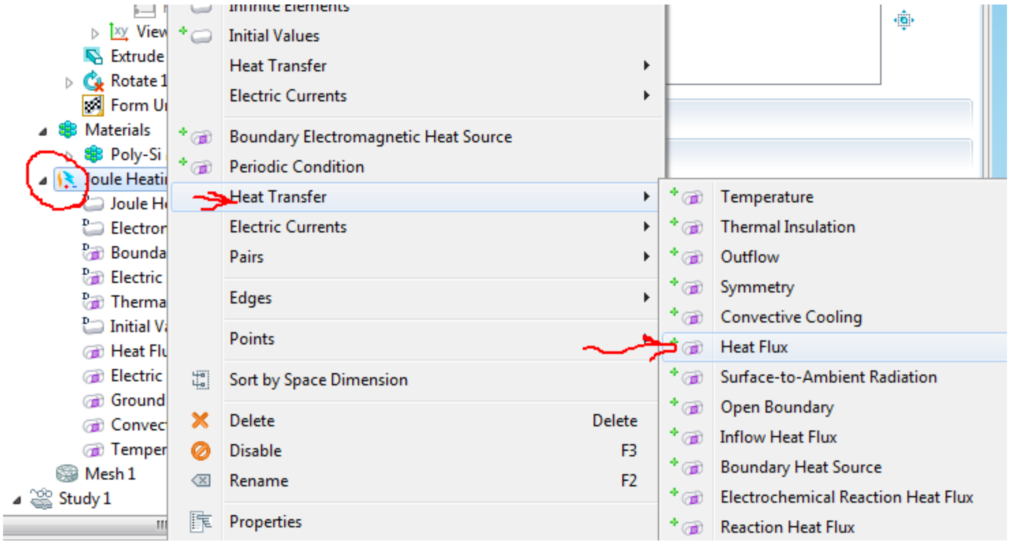


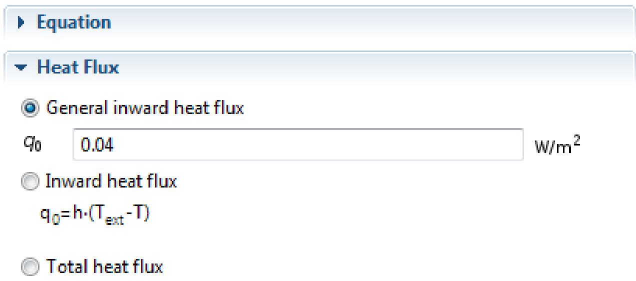
Then, go to Union and click Buld all.
Next, Extrude the 2D image we made.

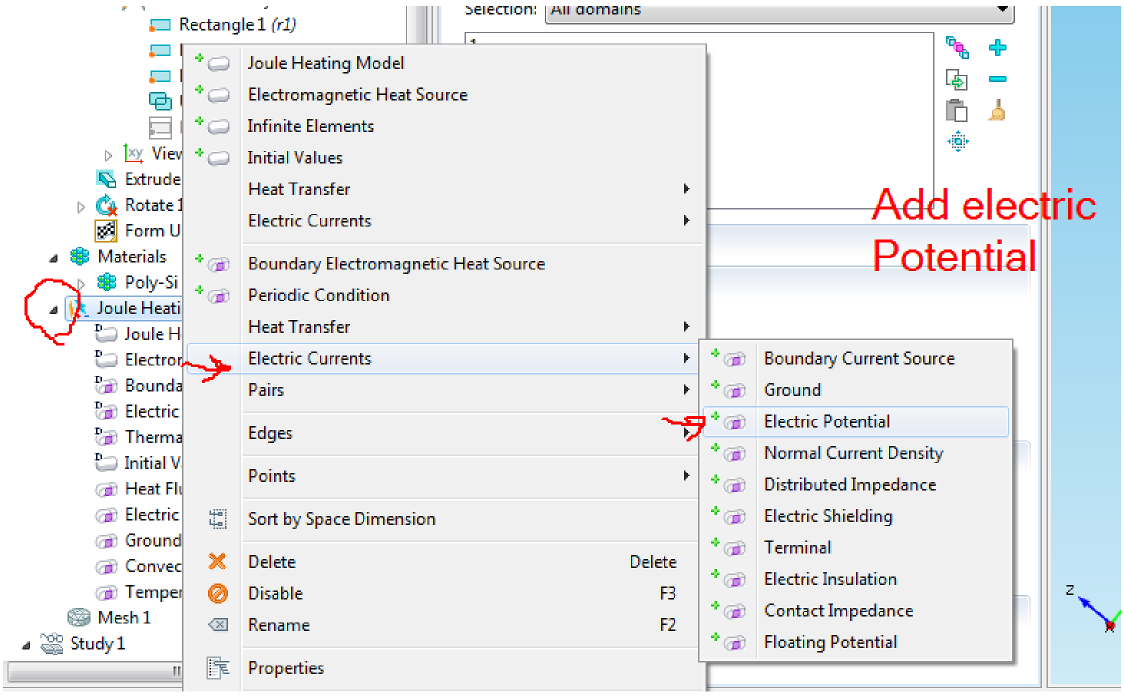


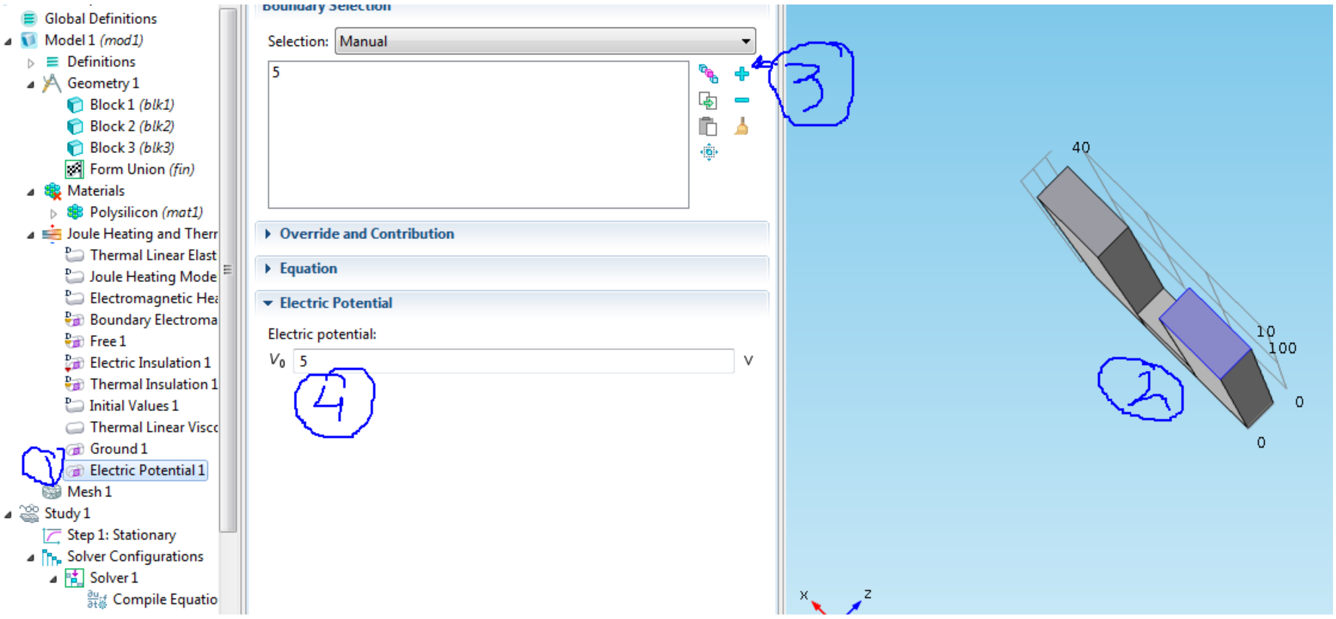

Search
Batteries and Fuel Cells
Liquids and Gases
MEMS
Metals
Semiconductors
C [100]
GaAs
Ge
InSb
Si(c)
Poly-Si
Silicon (single-crystal)
Phase:
Go to Material Browser

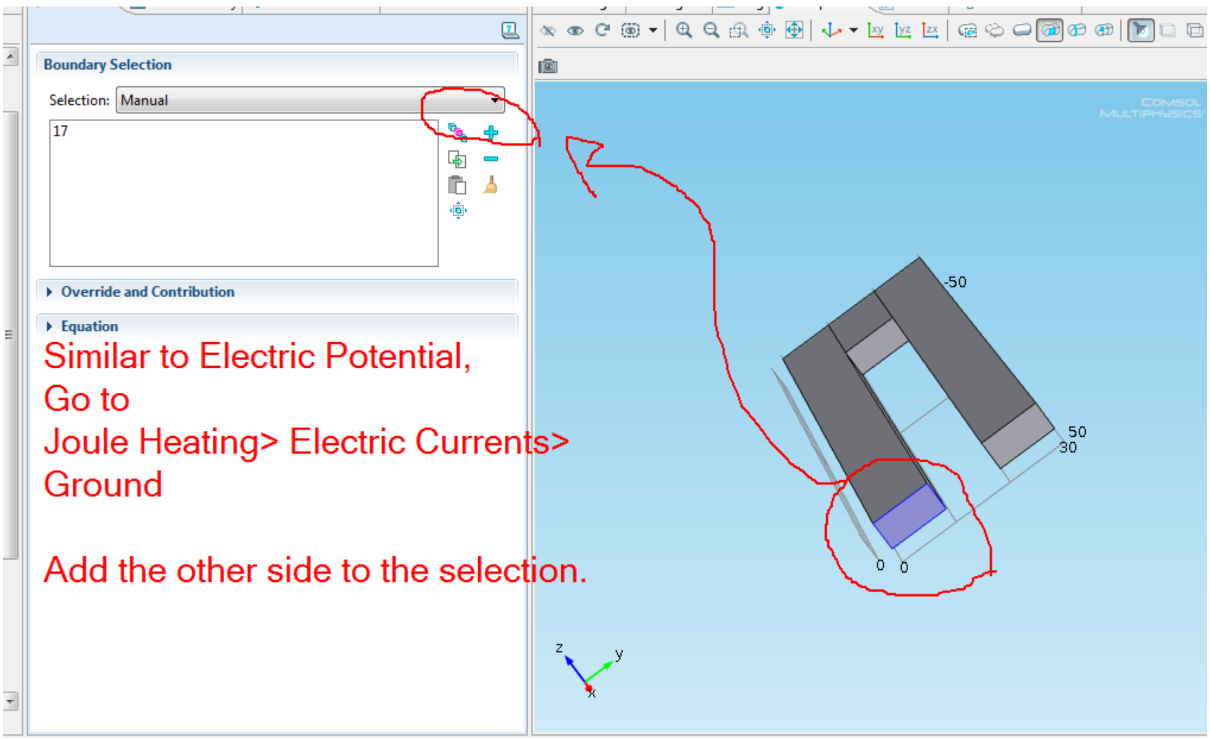

Geometric Entity Selection
Geometric entity level: Domain
Selection: All domains
1
2
3
Add the value of Electrical Conductivity
Override
Material Properties
Material Contents
Property Name Value Unit
Heat capacity at constant pr... Cp 678[J/(... J/(kg...
Relative permittivity epsil... 4.5 1
Density rho 2320[k... kg/...
Thermal conductivity k 0.04 W/(...
Electrical conductivity sigma 5e4 S/m
Coefficient of thermal expan... alpha 2.6e-6[... 1/K
Young's modulus E 160e9[... Pa
Poisson's ratio nu 0.22 1

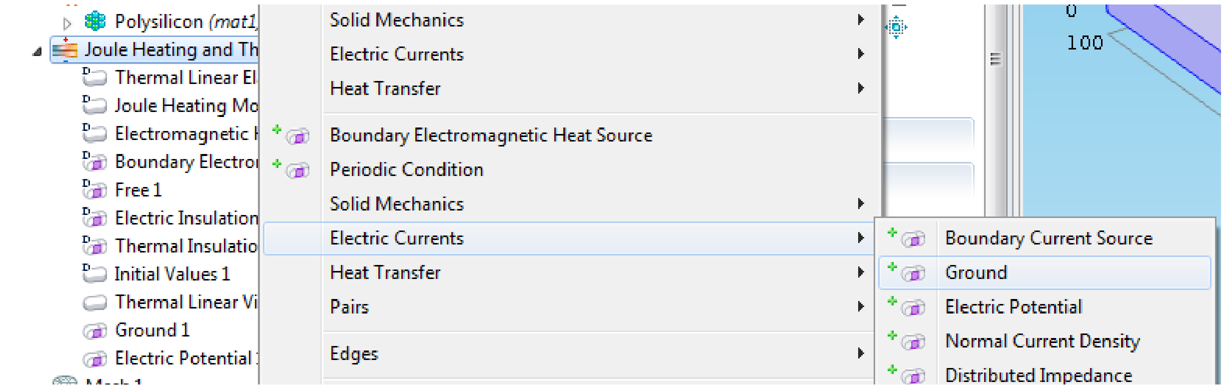

Initial Values
Heat Transfer
Electric Currents
Boundary Electromagnetic Heat Source
Periodic Condition
Heat Transfer
Electric Currents
Pairs
Edges
Points
Sort by Space Dimension
Delete Delete
Disable F3
Rename F2
Properties
Temperature
Thermal Insulation
Outflow
Symmetry
Convective Cooling
Heat Flux
Surface-to-Ambient Radiation
Open Boundary
Inflow Heat Flux
Boundary Heat Source
Electrochemical Reaction Heat Flux
Reaction Heat Flux
Materials
Poly-Si
Mesh 1
Study 1

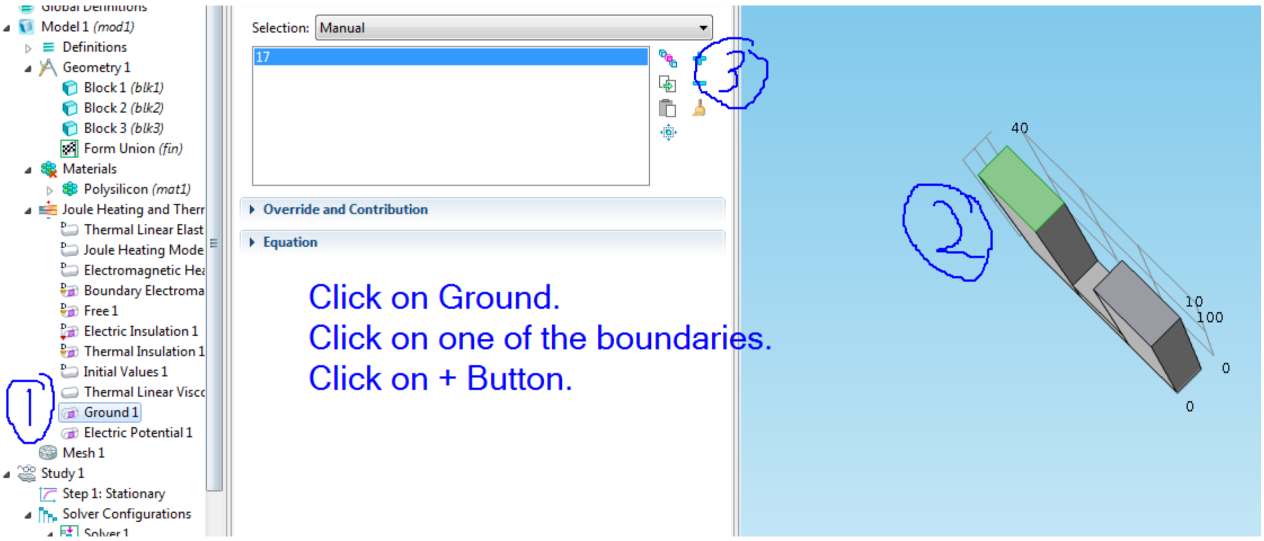

Equation
Heat Flux
General inward heat flux
q_0 0.04 W/m^2
Inward heat flux
$q_0=h\cdot(T_{ext}-T)$
Total heat flux

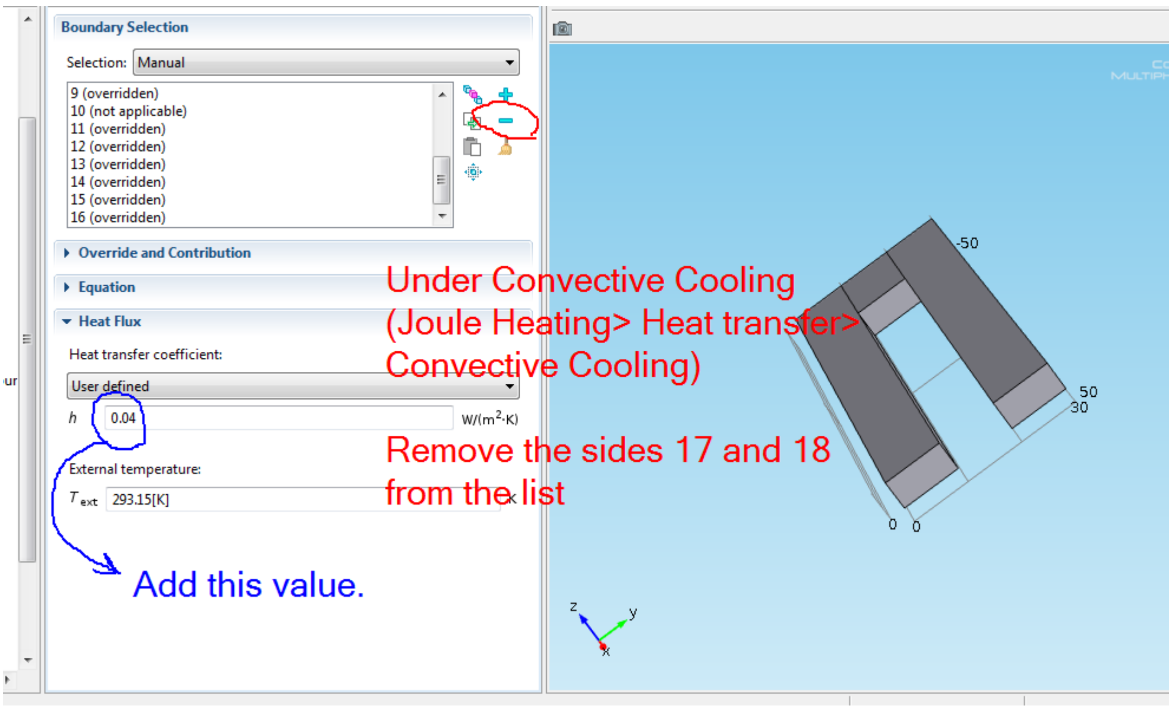

Rectangle 1 (r1)
Joule Heating Model
Electromagnetic Heat Source
Infinite Elements
Initial Values
Heat Transfer
Electric Currents
Boundary Electromagnetic Heat Source
Periodic Condition
Heat Transfer
Electric Currents
Pairs
Edges
Points
Sort by Space Dimension
Delete Delete
Disable F3
Rename F2
Properties
Boundary Current Source
Ground
Electric Potential
Normal Current Density
Distributed Impedance
Electric Shielding
Terminal
Electric Insulation
Contact Impedance
Floating Potential
Add electric Potential
Materials
Poly-Si
Mesh 1
Study 1

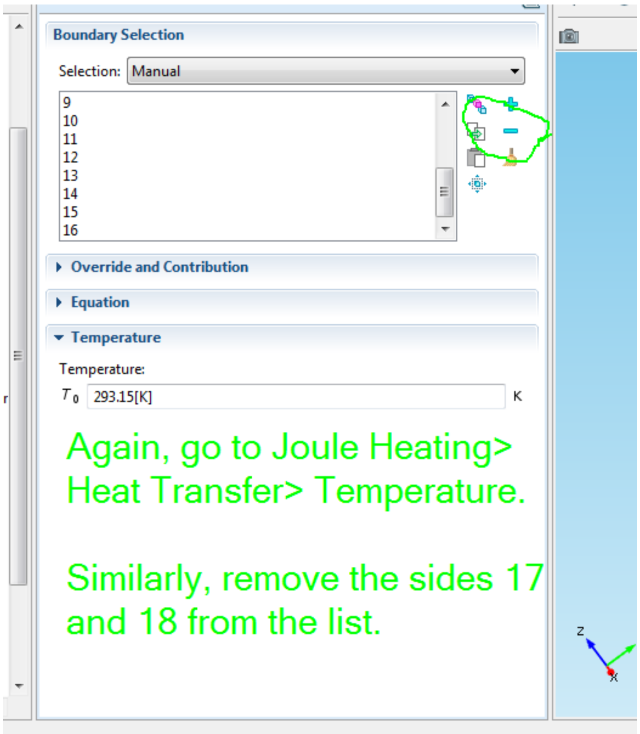

Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Block 2 (blk2)
Block 3 (blk3)
Form Union (fin)
Materials
Polysilicon (mat1)
Ground 1
Electric Potential 1
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Solver 1
Selection: Manual
5
Override and Contribution
Equation
Electric Potential
Electric potential:
V_0 5 V
1
2
3
4

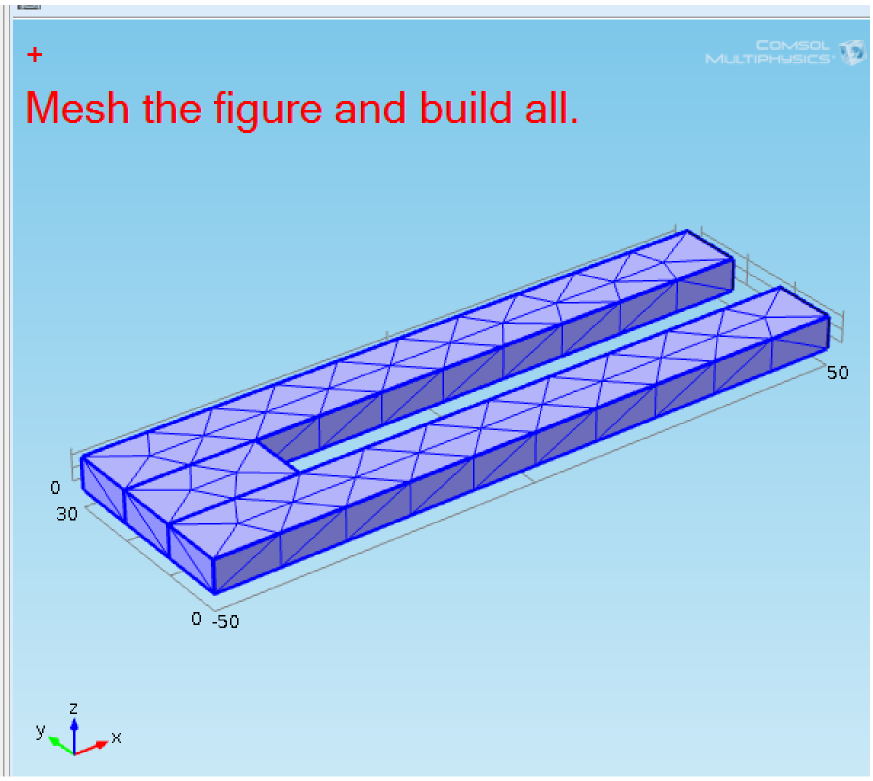

Boundary Selection
Selection: Manual
17
Override and Contribution
Equation
Similar to Electric Potential,
Go to
Joule Heating> Electric Currents>
Ground
Add the other side to the selection.

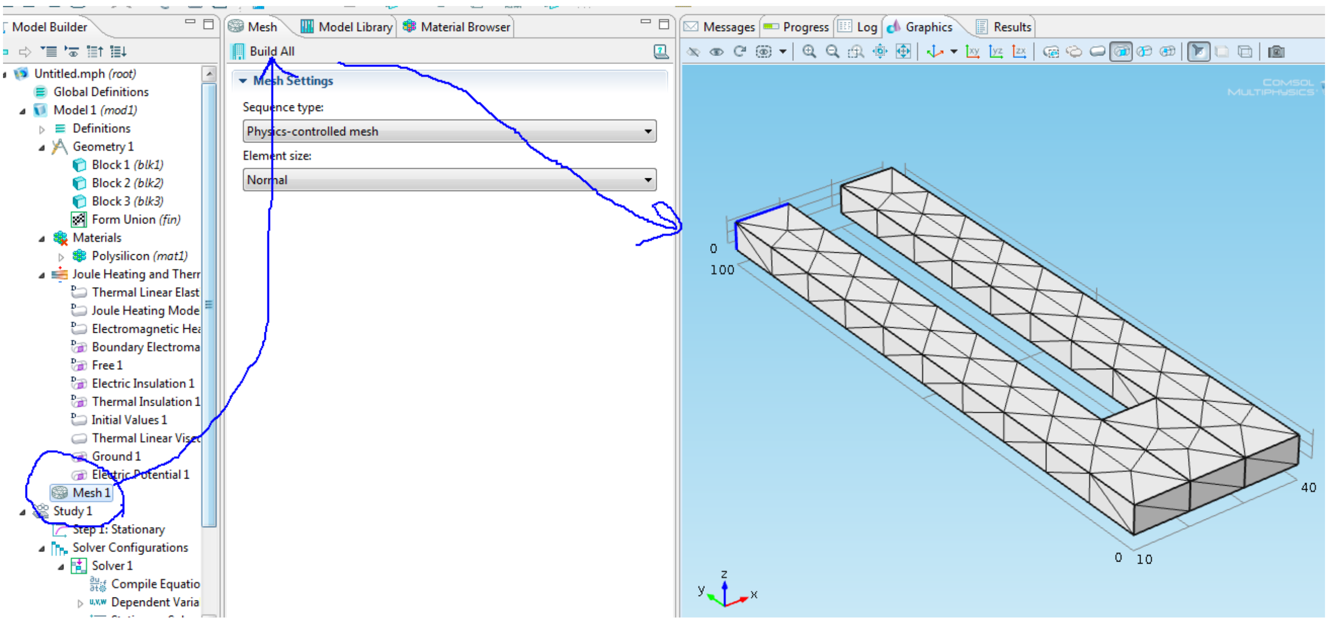

Polysilicon (mat1)
Joule Heating and Th
Thermal Linear El
Joule Heating Mo
Electromagnetic
Boundary Electro
Free 1
Electric Insulation
Thermal Insulatio
Initial Values 1
Thermal Linear Vi
Ground 1
Electric Potential
Solid Mechanics
Electric Currents
Heat Transfer
Boundary Electromagnetic Heat Source
Periodic Condition
Solid Mechanics
Electric Currents
Heat Transfer
Pairs
Edges
Boundary Current Source
Ground
Electric Potential
Normal Current Density
Distributed Impedance

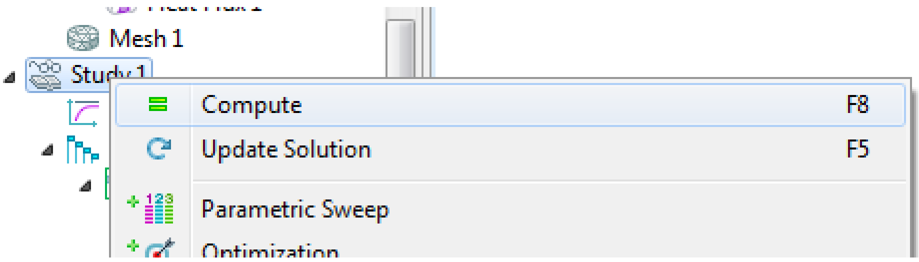

Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Block 2 (blk2)
Block 3 (blk3)
Form Union (fin)
Materials
Polysilicon (mat1)
Joule Heating and Therr
Thermal Linear Elast
Joule Heating Mode
Electromagnetic Hea
Boundary Electroma
Free 1
Electric Insulation 1
Thermal Insulation 1
Initial Values 1
Thermal Linear Visco
Ground 1
Electric Potential 1
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Selection: Manual
17
Override and Contribution
Equation
Click on Ground.
Click on one of the boundaries.
Click on + Button.

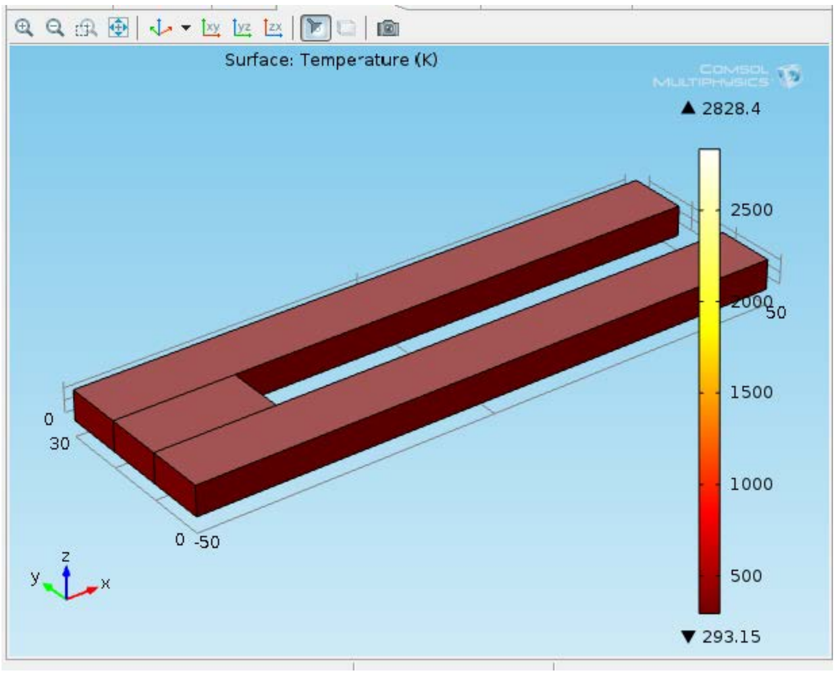

Boundary Selection
Selection: Manual
9 (overridden)
10 (not applicable)
11 (overridden)
12 (overridden)
13 (overridden)
14 (overridden)
15 (overridden)
16 (overridden)
Override and Contribution
Equation
Heat Flux
Heat transfer coefficient:
User defined
h 0.04 W/(m²·K)
External temperature:
T ext 293.15[K]
Add this value.
Under Convective Cooling
(Joule Heating> Heat transfer>
Convective Cooling)
Remove the sides 17 and 18
from the list

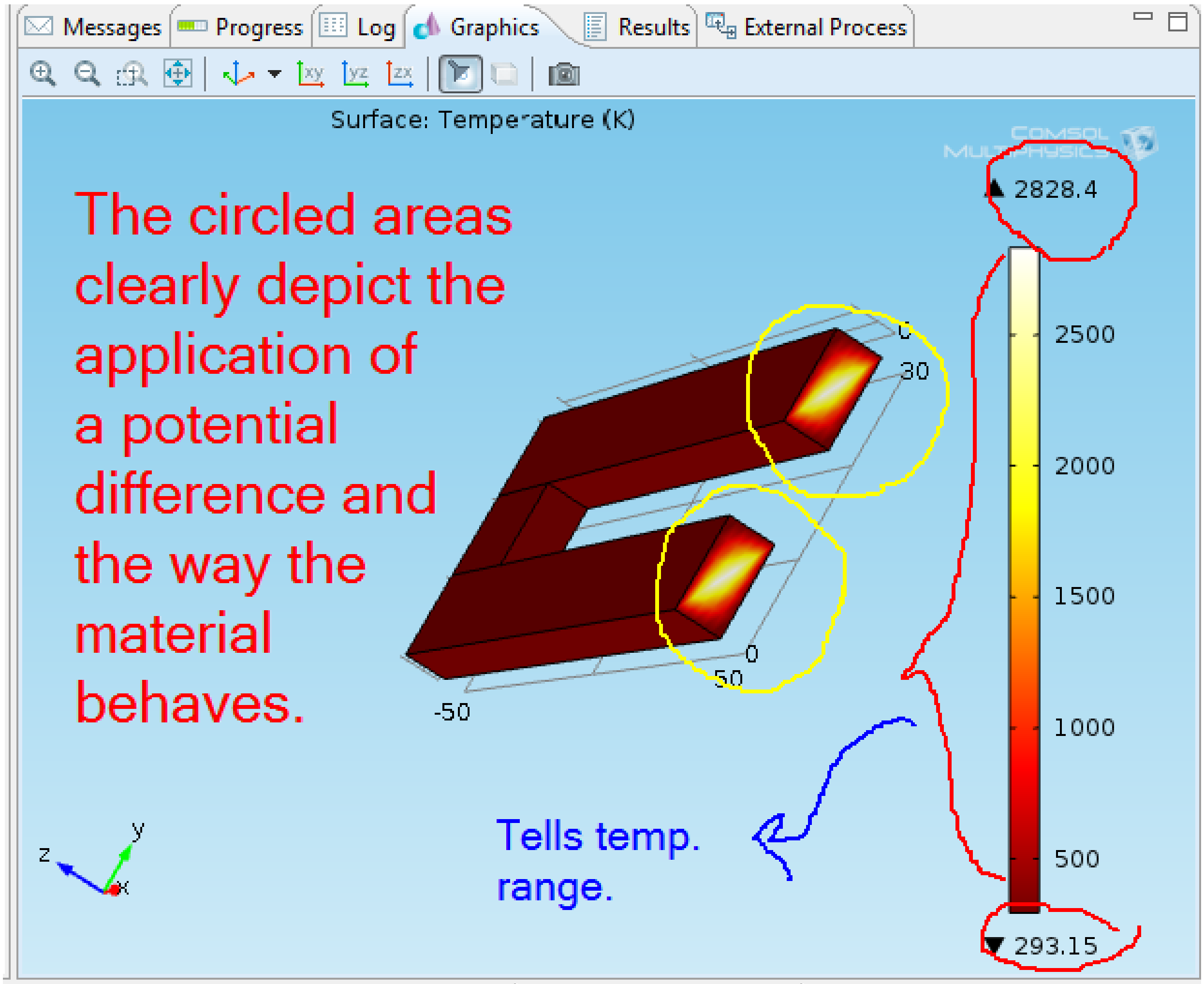

Boundary Selection
Selection: Manual
9
10
11
12
13
14
15
16
Override and Contribution
Equation
Temperature
Temperature:
T_0 293.15[K] K
Again, go to Joule Heating> Heat Transfer> Temperature.
Similarly, remove the sides 17 and 18 from the list.


Mesh the figure and build all.
COMSOL MULTIPHYSICS
50
0
30
0 -50


Model Builder
Mesh
Model Library
Material Browser
Messages
Progress
Log
Graphics
Results
Build All
Mesh Settings
Sequence type:
Physics-controlled mesh
Element size:
Normal
Untitled.mph (root)
Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Block 2 (blk2)
Block 3 (blk3)
Form Union (fin)
Materials
Polysilicon (mat1)
Joule Heating and Therr
Thermal Linear Elast
Joule Heating Mode
Electromagnetic Hea
Boundary Electroma
Free 1
Electric Insulation 1
Thermal Insulation 1
Initial Values 1
Thermal Linear Visc
Ground 1
Electric Potential 1
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Solver 1
Compile Equatio
Dependent Varia


Mesh 1
Study 1
Compute F8
Update Solution F5
Parametric Sweep
Optimization


Surface: Temperature (K)
▲ 2828.4
2500
2000
1500
1000
500
▼ 293.15

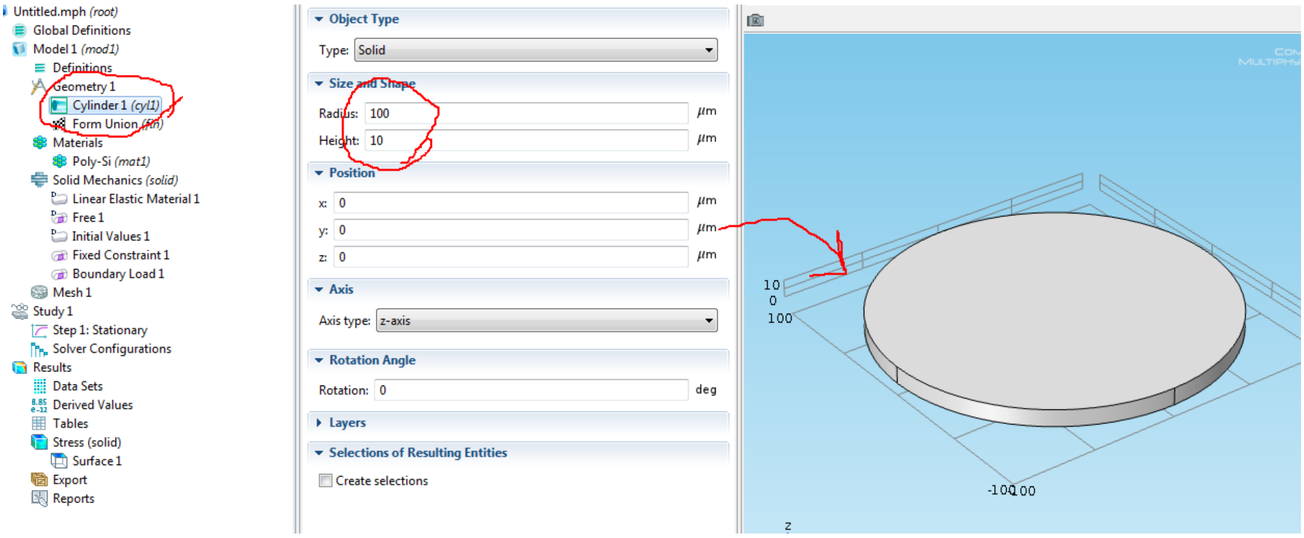

Messages
Progress
Log
Graphics
Results
External Process
Surface: Temperature (K)
The circled areas clearly depict the application of a potential difference and the way the material behaves.
Tells temp. range.
2828.4
2500
2000
1500
1000
500
293.15
-50
0
50
0
30
z
y
x

Analysis of Circular diaphragm in micro pressure sensor and find the deflection

We have to make a disk (or a thin cylinder)
Now, apply pressure at its top and analyze the figure we get.

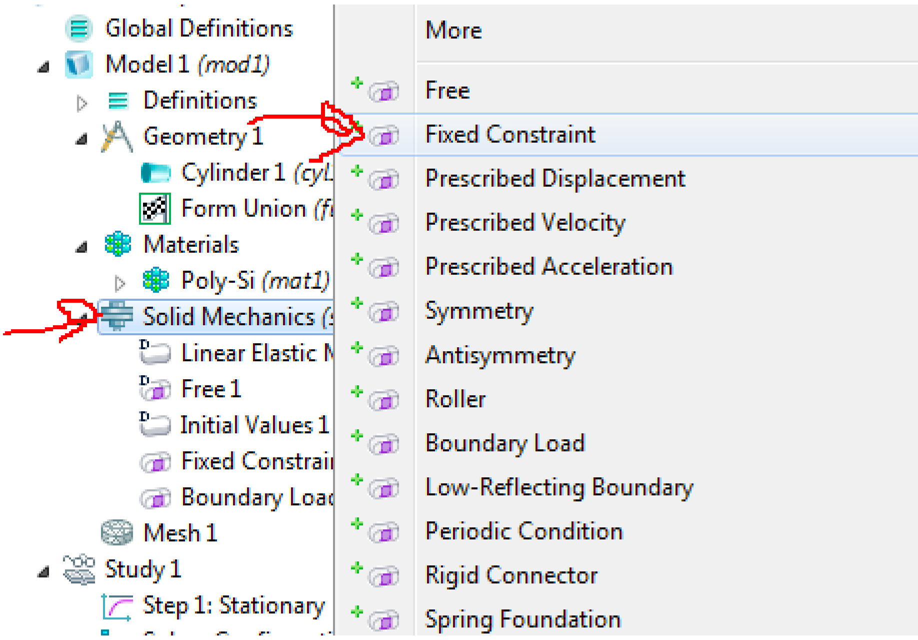
Initial steps - 3D > Solid Mechanics (solid) > Stationary

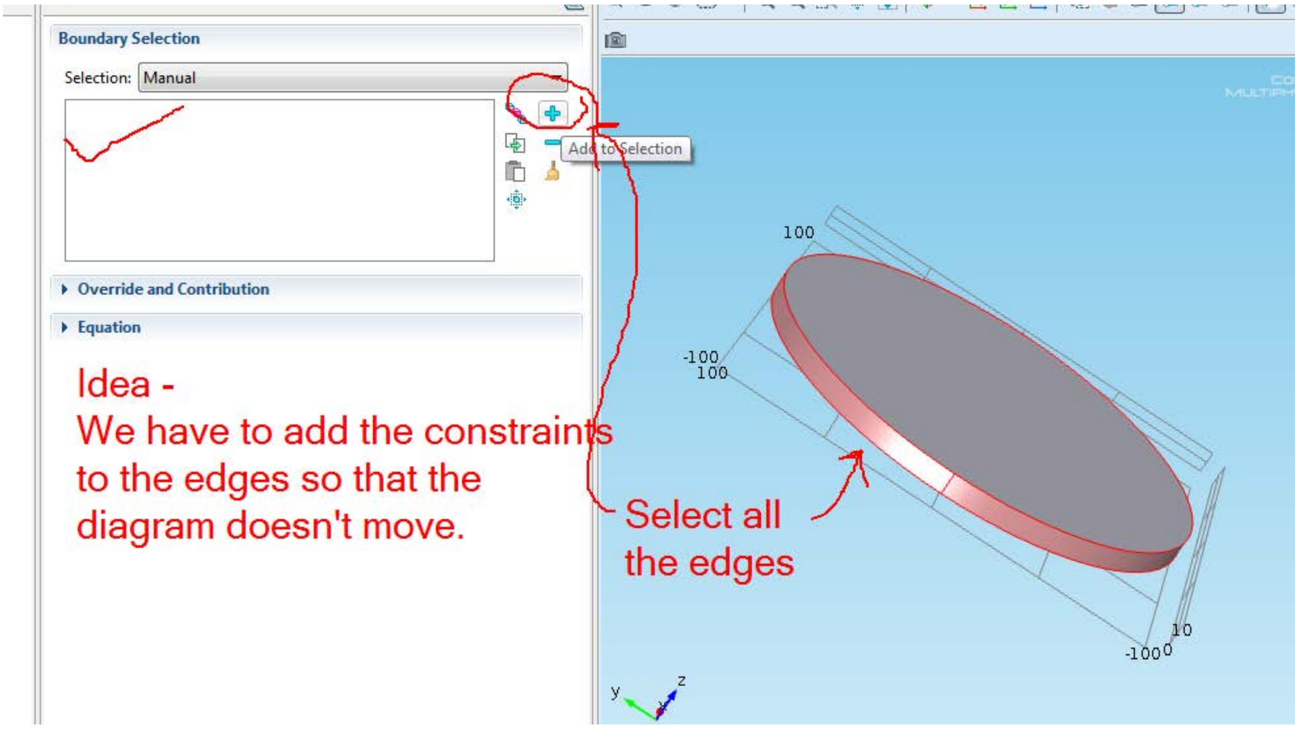
Select cylinder in Geometry and take the following dimensions -



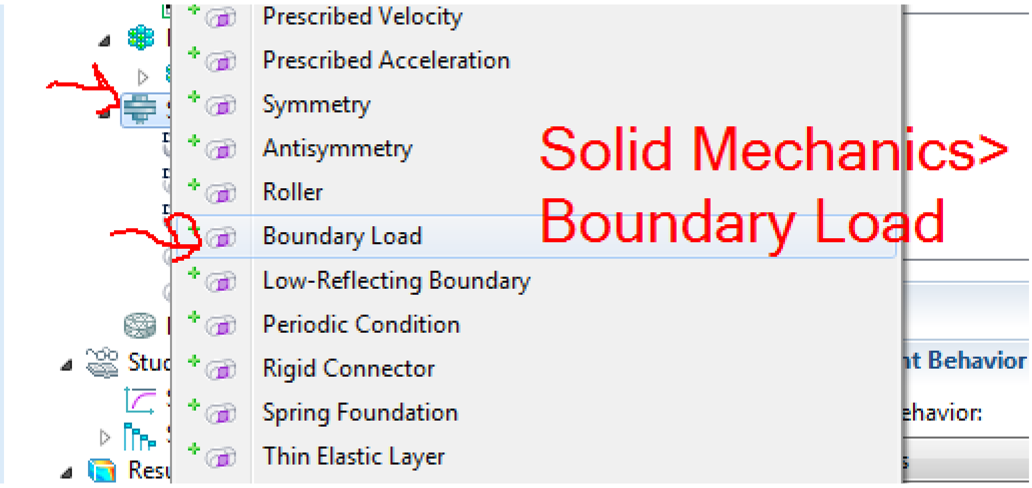
Now,
Select the material -
Poly-Si

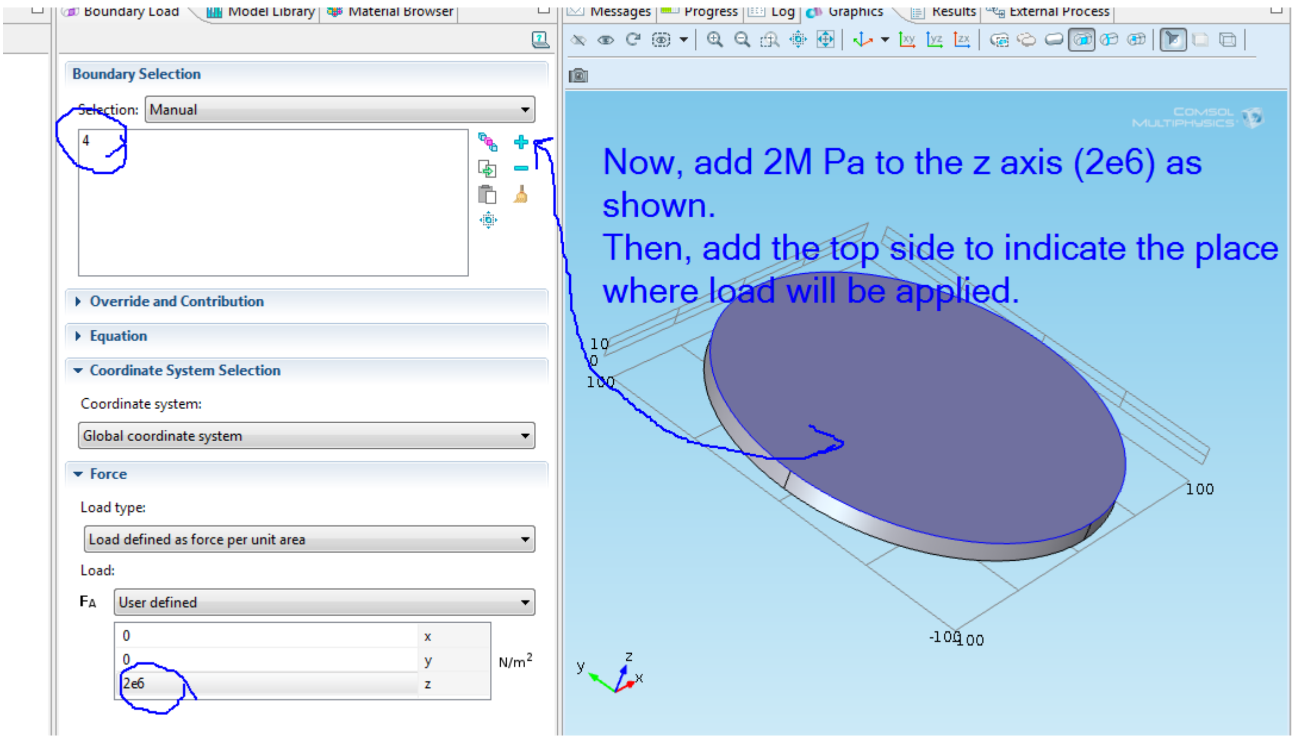
Next,
Click on Solid Mechanics.
Right click and add -
Fixed Constraint.





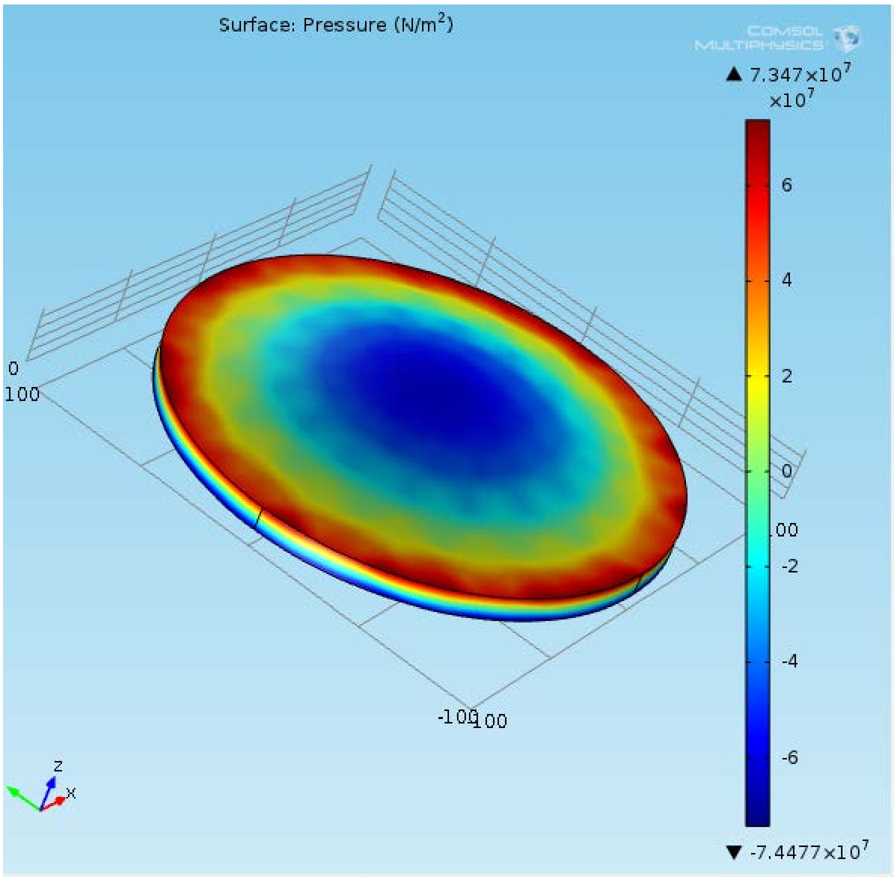
Now, once the base is set, we need to add load over the top or bottom.
For that use Boundary load option.



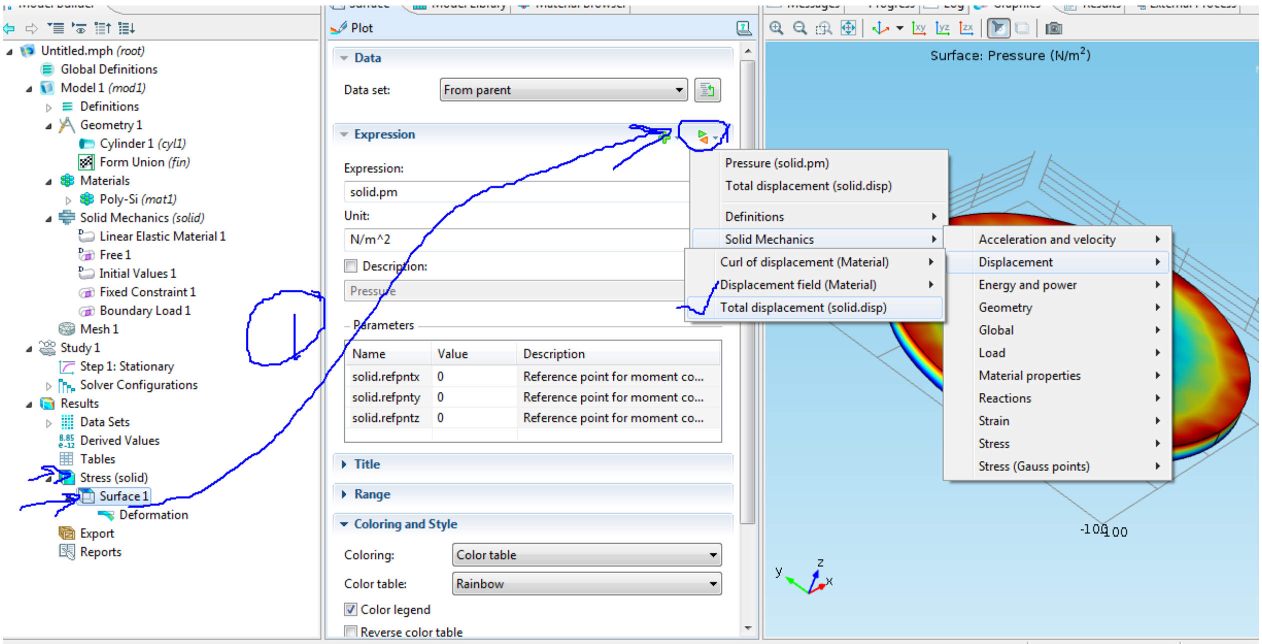


Next, go to Mesh and Build All.

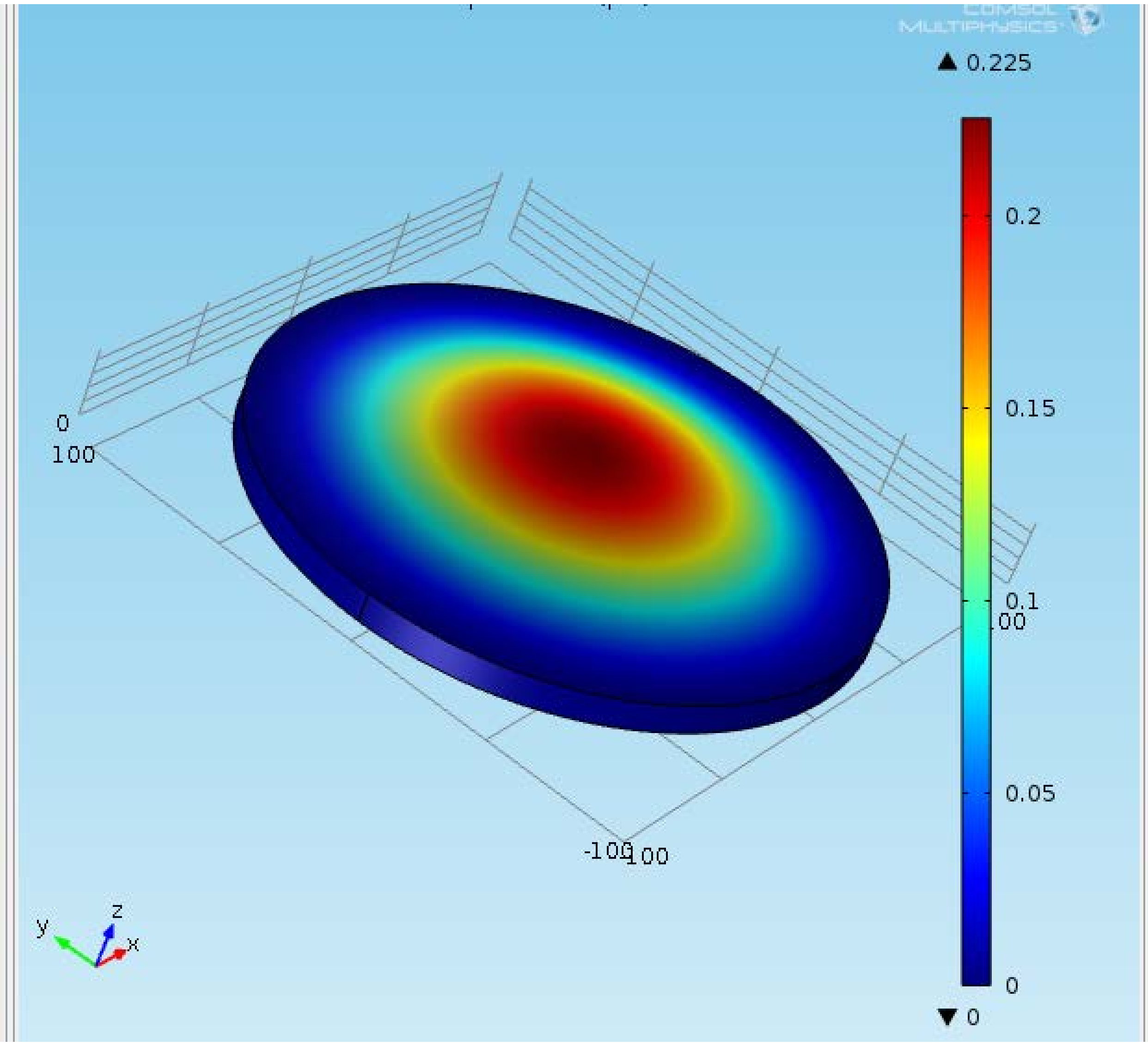
Finally, Study 1 > Compute.



Now, to see the total displacement,
Stress> Surface

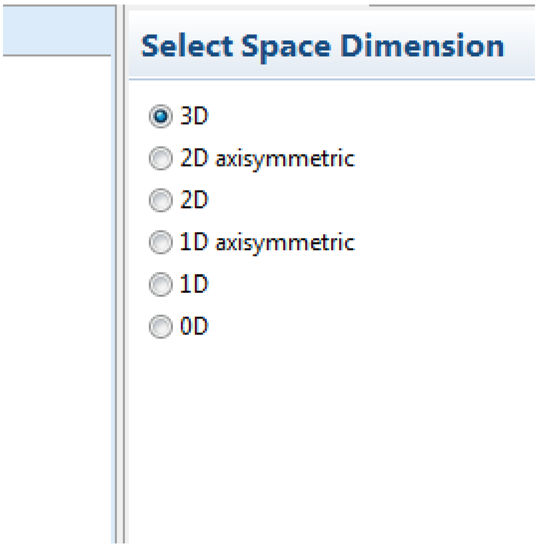


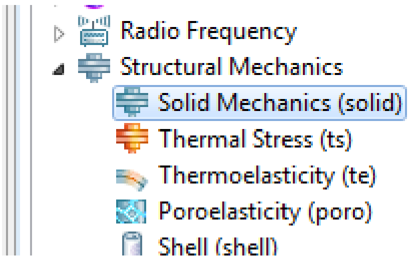
Then, Click on Plot.

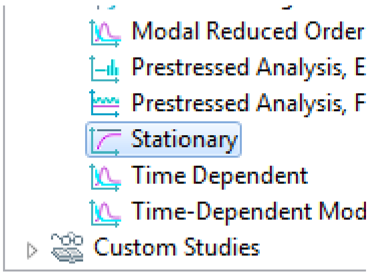


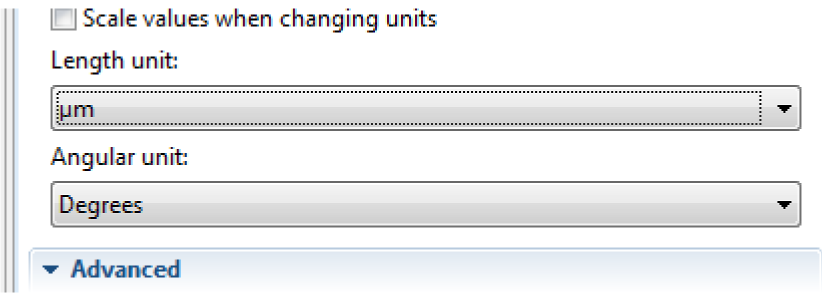
Similarly, the dimensions of the disk can be changed and we can see for different values.
Done!

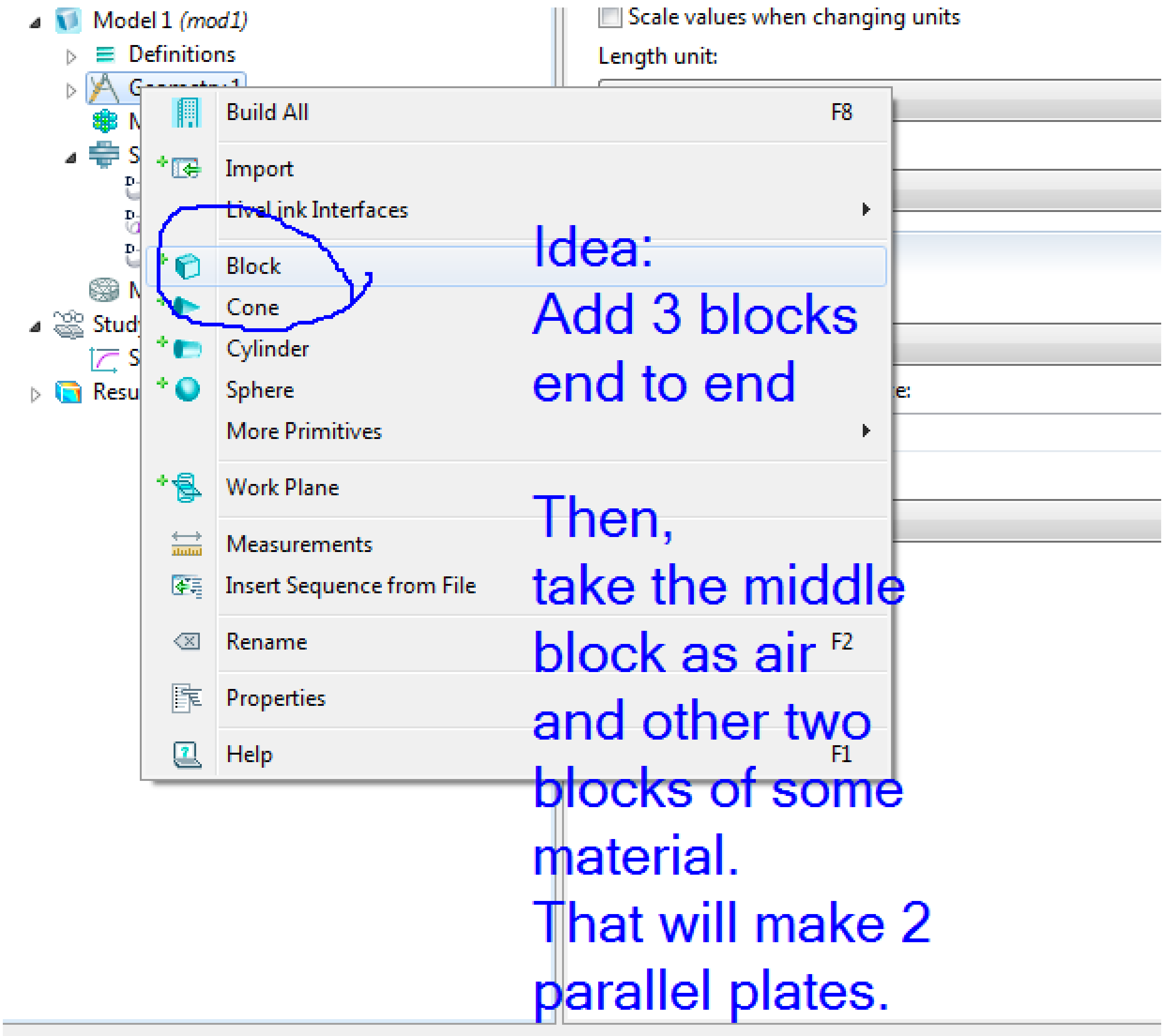
Making a Capacitor



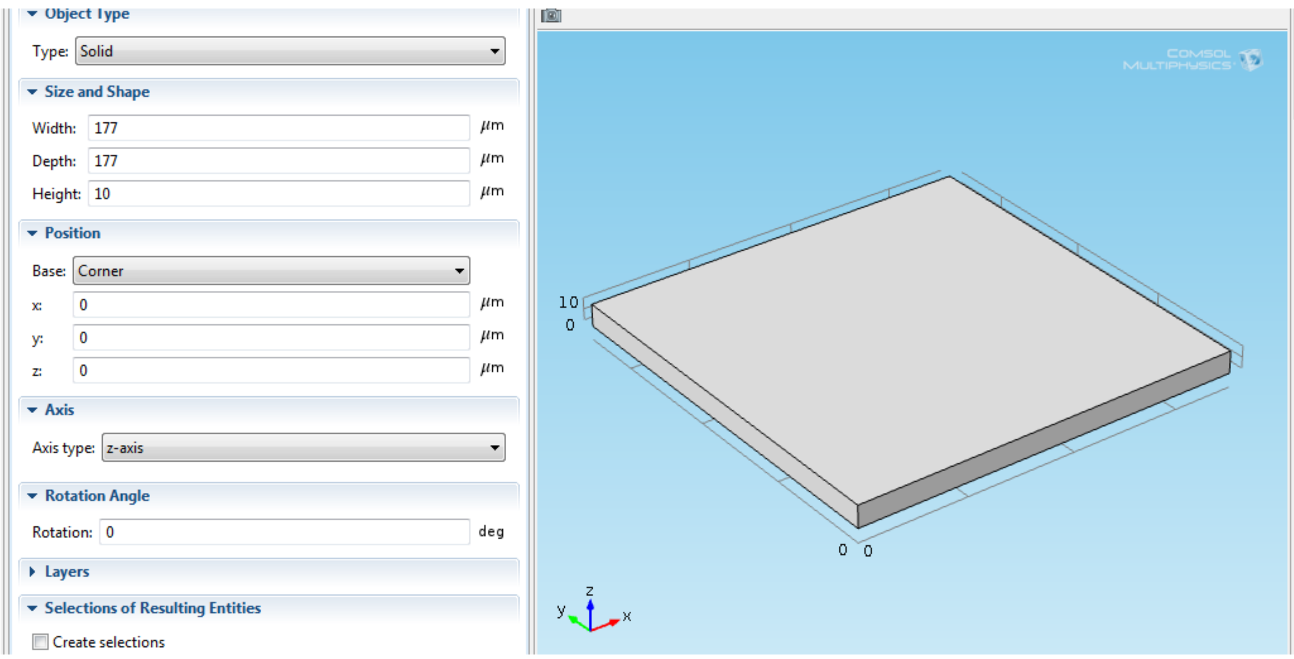




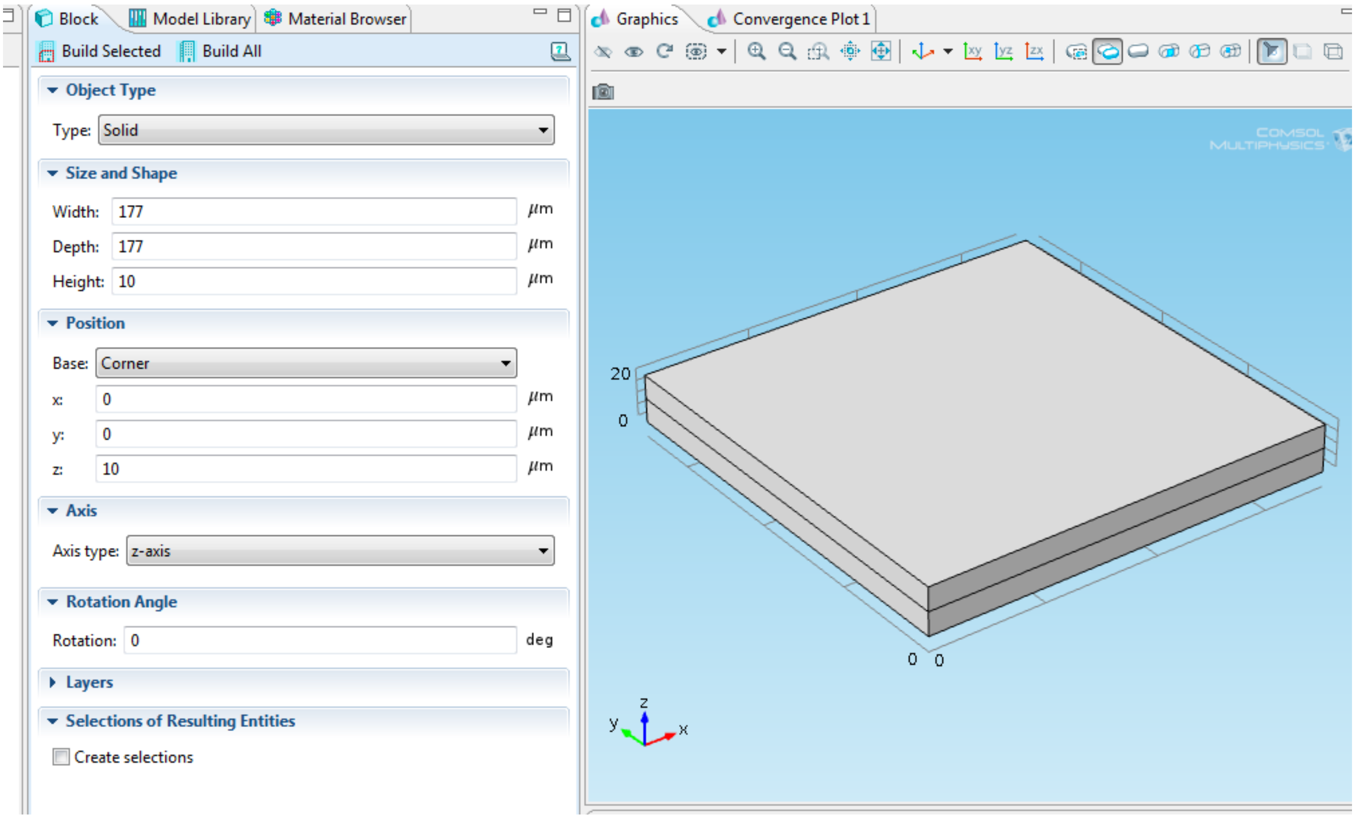


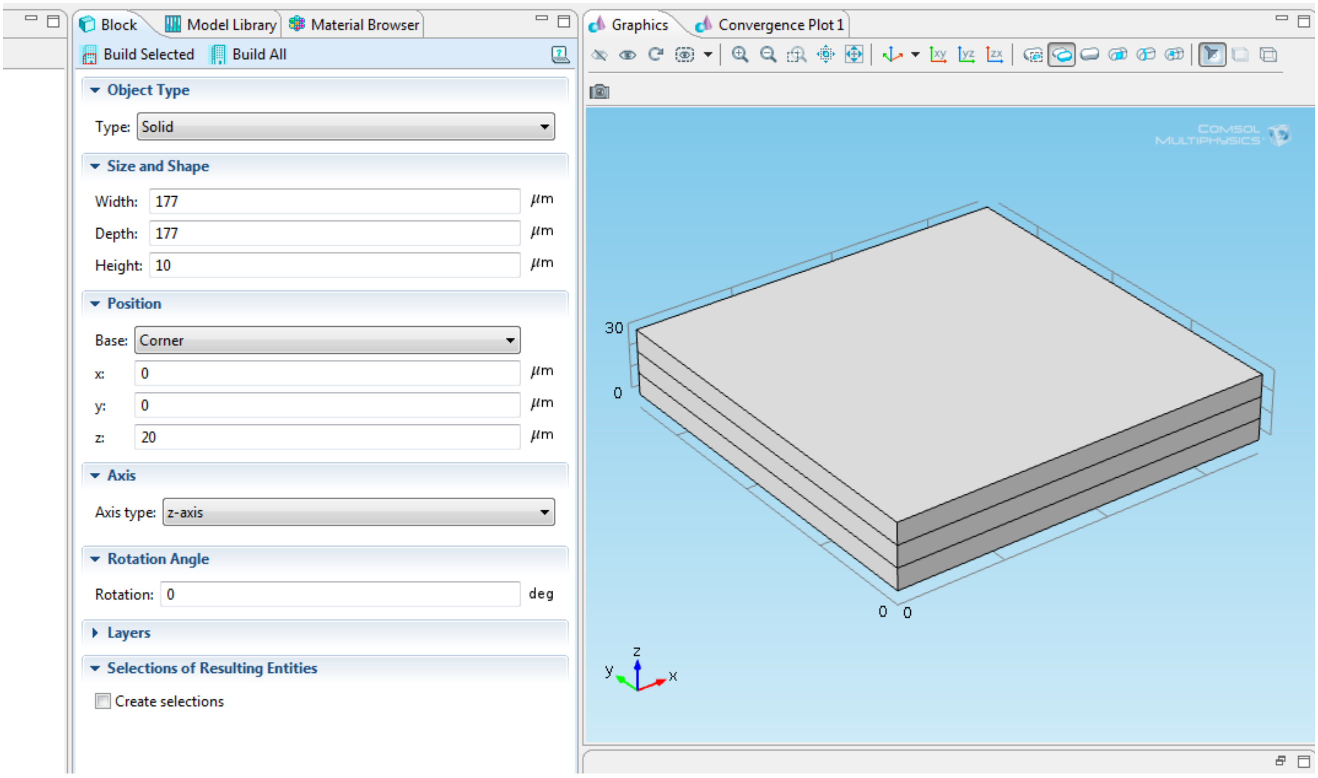


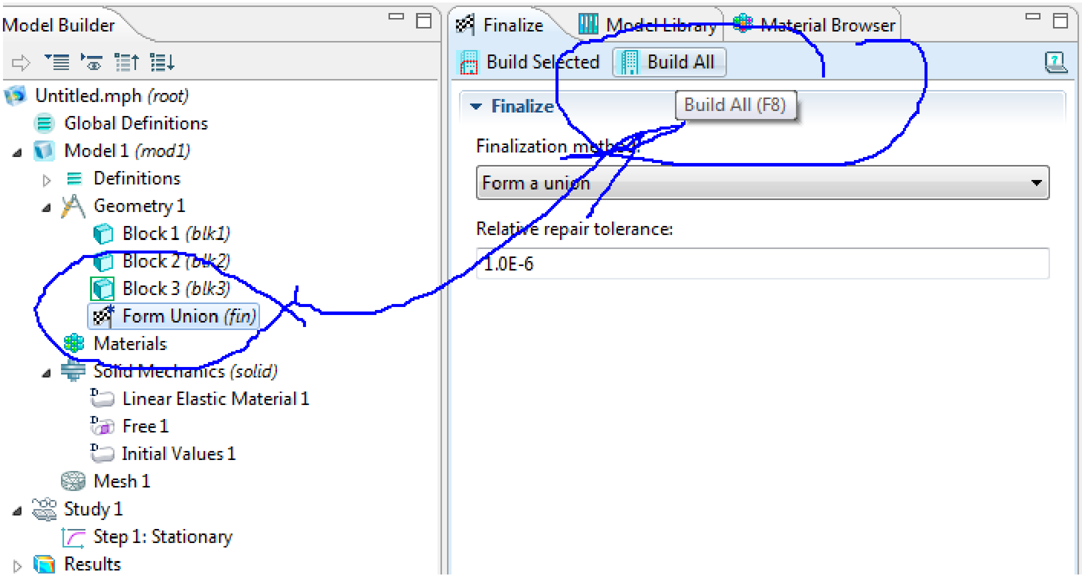
Model 1 (mod1)
Definitions
Scale values when changing units
Length unit:
Build All F8
Import
LiveLink Interfaces
Block
Cone
Cylinder
Sphere
More Primitives
Work Plane
Measurements
Insert Sequence from File
Rename F2
Properties
Help F1
Idea:
Add 3 blocks
end to end
Then,
take the middle
block as air
and other two
blocks of some
material.
That will make 2
parallel plates.

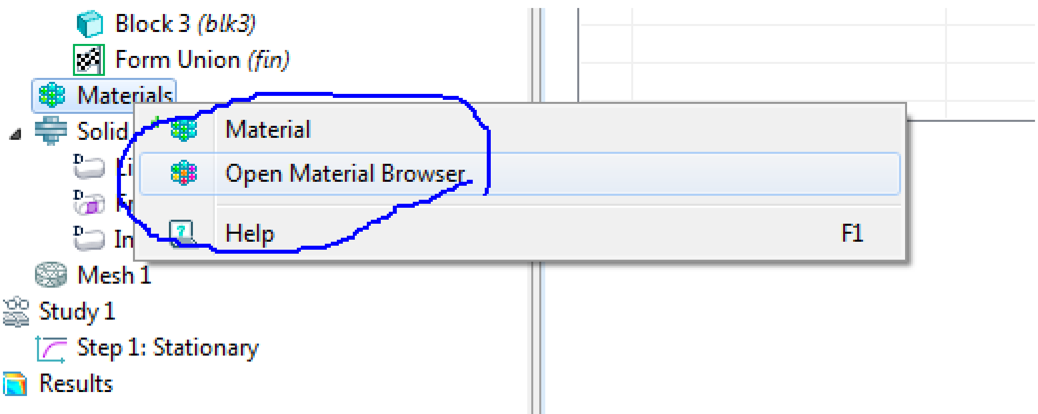


Object Type
Type: Solid
Size and Shape
Width: 177 µm
Depth: 177 µm
Height: 10 µm
Position
Base: Corner
x: 0 µm
y: 0 µm
z: 0 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities
Create selections

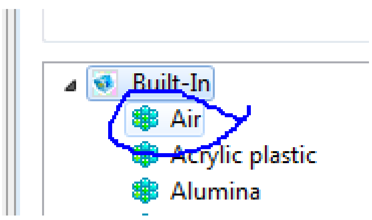

Block
Model Library
Material Browser
Build Selected
Build All
Object Type
Type: Solid
Size and Shape
Width: 177 µm
Depth: 177 µm
Height: 10 µm
Position
Base: Corner
x: 0 µm
y: 0 µm
z: 10 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities
Create selections
Graphics
Convergence Plot 1
20
0
0 0
z
y
x

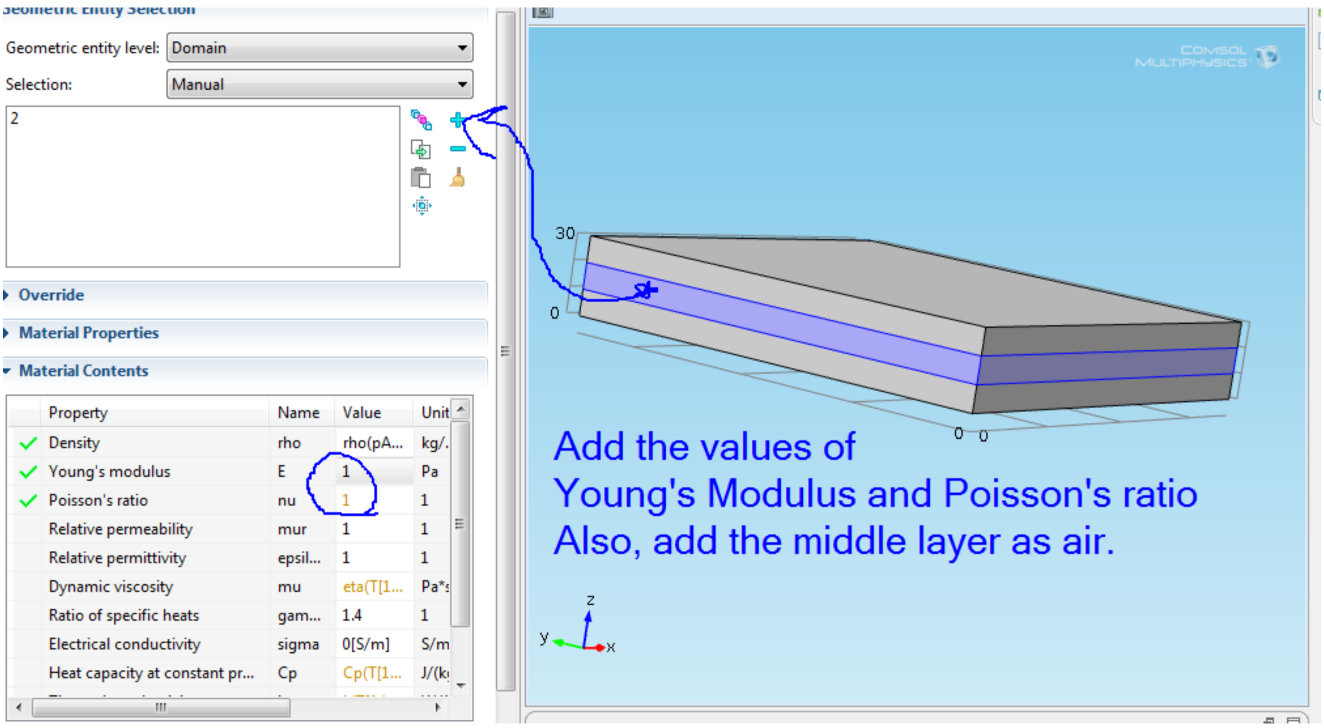

Block
Model Library
Material Browser
Build Selected
Build All
Object Type
Type: Solid
Size and Shape
Width: 177 µm
Depth: 177 µm
Height: 10 µm
Position
Base: Corner
x: 0 µm
y: 0 µm
z: 20 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities
Create selections
Graphics
Convergence Plot 1
30
0
0 0
z
y
x

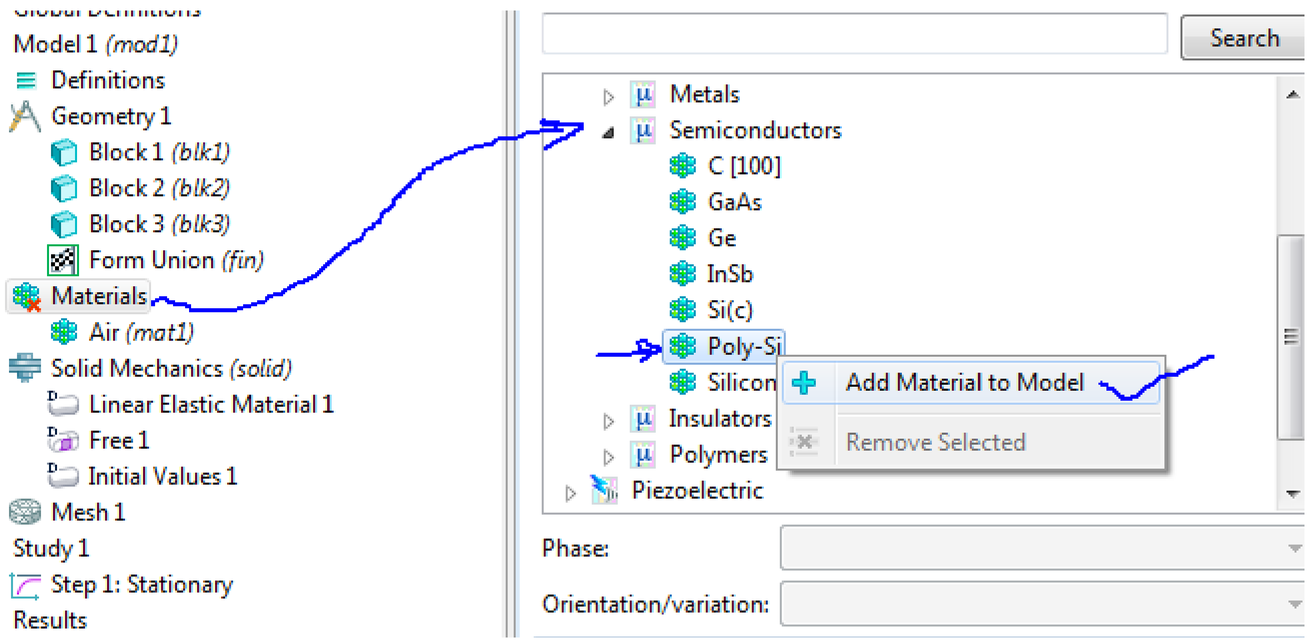


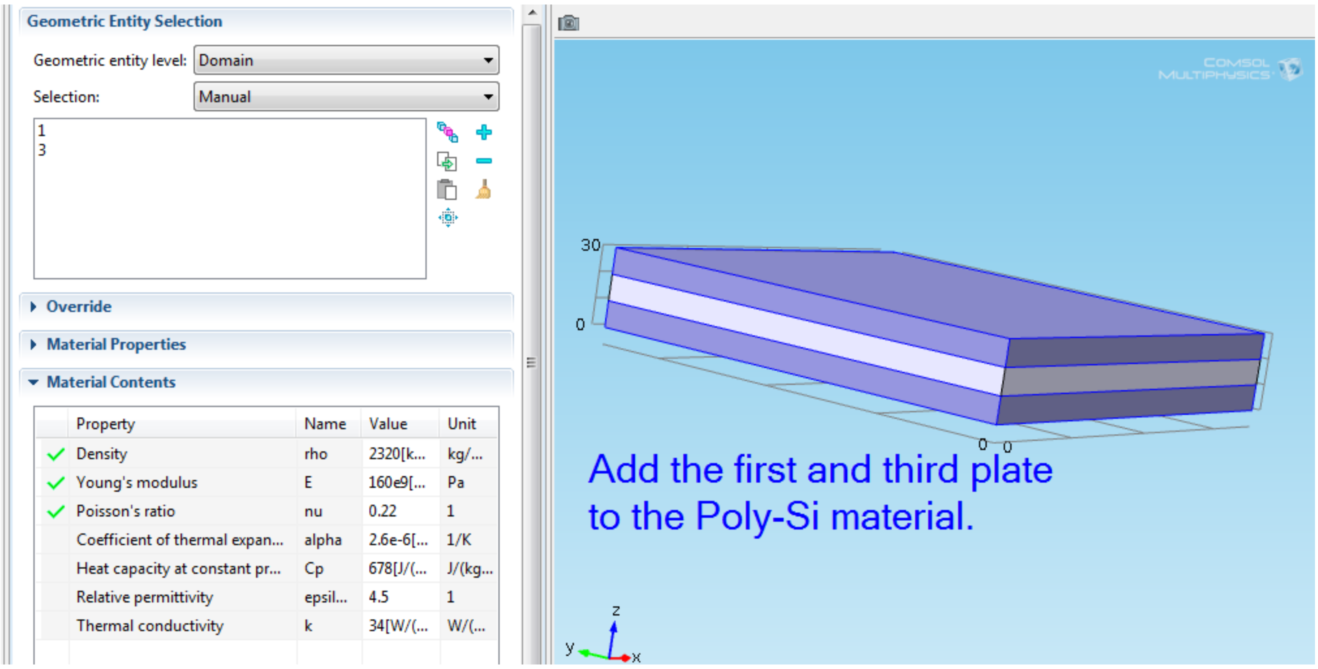


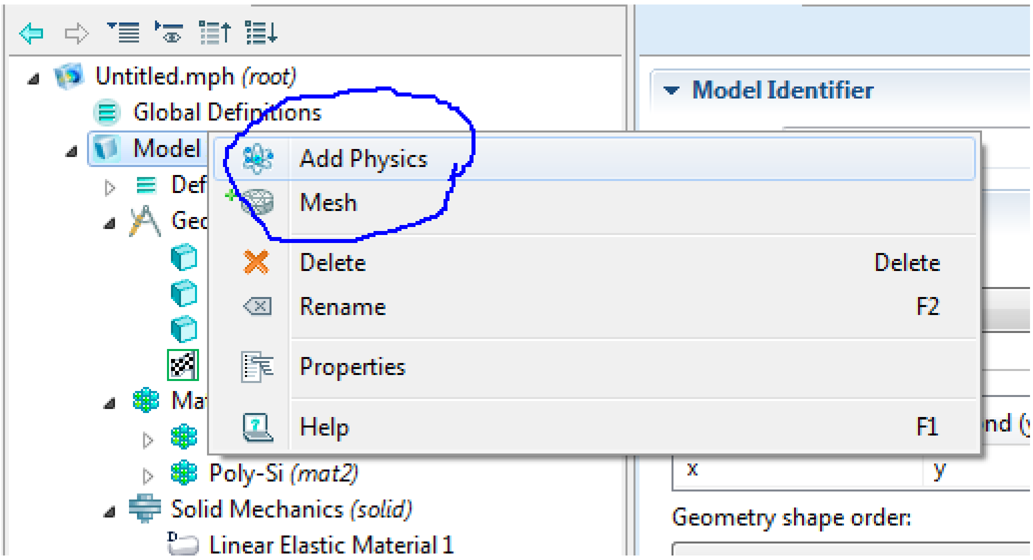
Add materials.

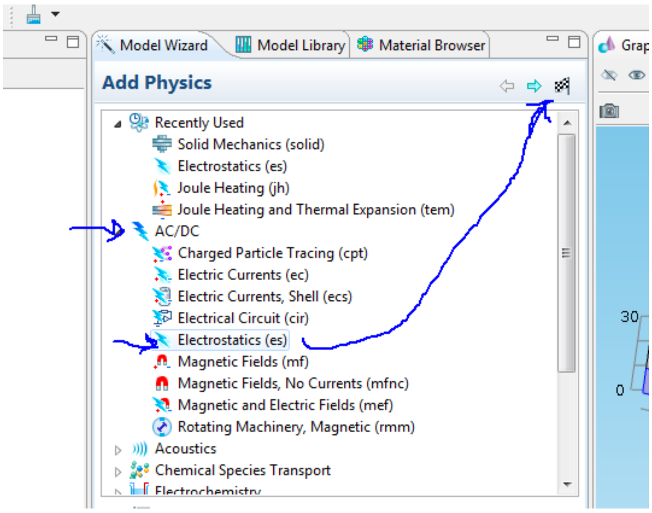


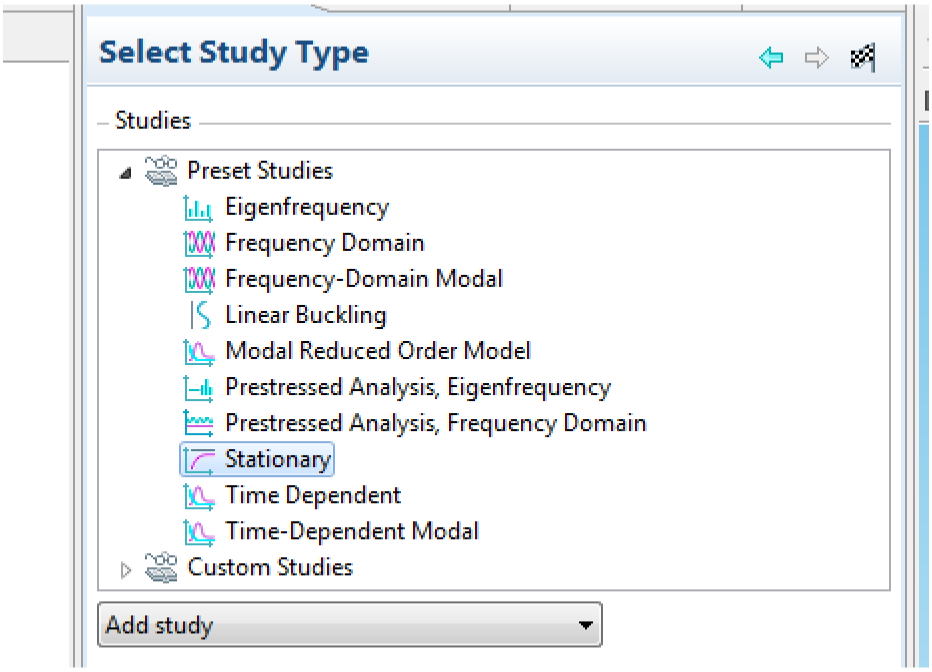

Geometric entity level: Domain
Selection: Manual
2
Override
Material Properties
Material Contents
Property Name Value Unit
Density rho rho(pA... kg/.
Young's modulus E 1 Pa
Poisson's ratio nu 1 1
Relative permeability mur 1 1
Relative permittivity epsil... 1 1
Dynamic viscosity mu eta(T[1... Pa*s
Ratio of specific heats gam... 1.4 1
Electrical conductivity sigma 0[S/m] S/m
Heat capacity at constant pr... Cp Cp(T[1... J/(k
Add the values of
Young's Modulus and Poisson's ratio
Also, add the middle layer as air.

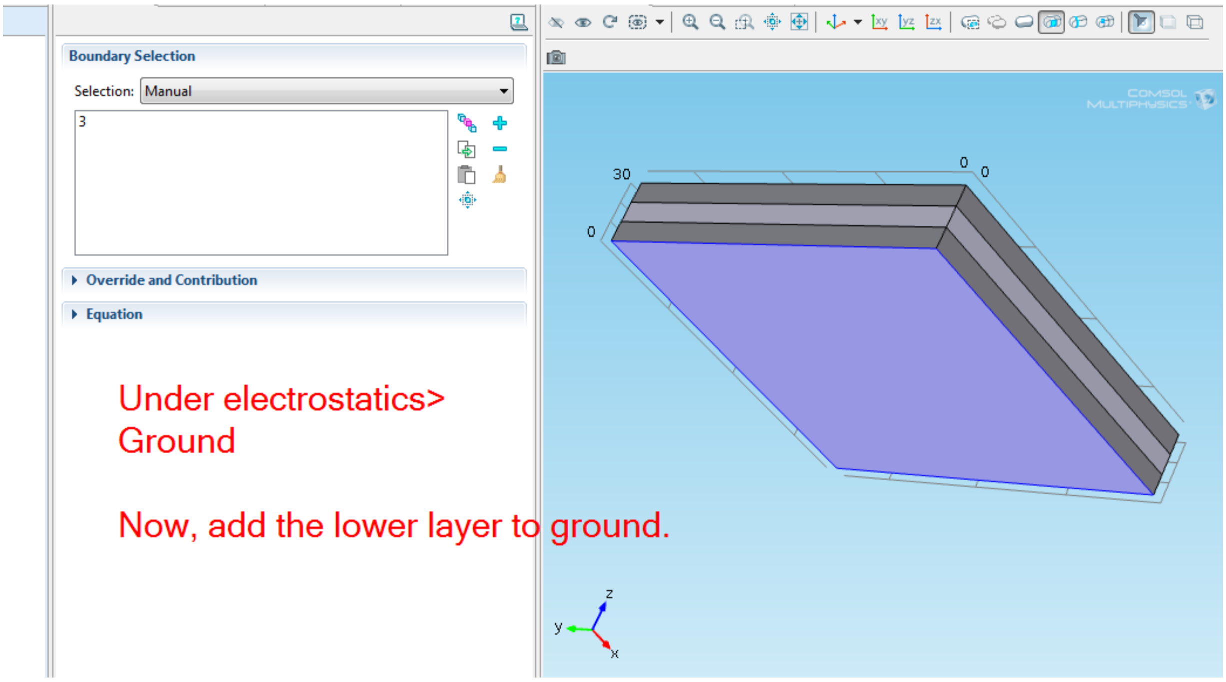

Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Block 2 (blk2)
Block 3 (blk3)
Form Union (fin)
Materials
Air (mat1)
Solid Mechanics (solid)
Linear Elastic Material 1
Free 1
Initial Values 1
Mesh 1
Study 1
Step 1: Stationary
Results
Search
Metals
Semiconductors
C [100]
GaAs
Ge
InSb
Si(c)
Poly-Si
Silicon
Insulators
Polymers
Piezoelectric
Add Material to Model
Remove Selected
Phase:
Orientation/variation:


Geometric Entity Selection
Geometric entity level: Domain
Selection: Manual
1
3
Override
Material Properties
Material Contents
Property | Name | Value | Unit
Density | rho | 2320[k... | kg/...
Young's modulus | E | 160e9[... | Pa
Poisson's ratio | nu | 0.22 | 1
Coefficient of thermal expan... | alpha | 2.6e-6[... | 1/K
Heat capacity at constant pr... | Cp | 678[J/(... | J/(kg...
Relative permittivity | epsil... | 4.5 | 1
Thermal conductivity | k | 34[W/(... | W/(...
Add the first and third plate
to the Poly-Si material.


Untitled.mph (root)
Global Definitions
Model
Add Physics
Mesh
Delete Delete
Rename F2
Properties
Help F1
Poly-Si (mat2)
Solid Mechanics (solid)
Linear Elastic Material 1
Model Identifier
Geometry shape order:

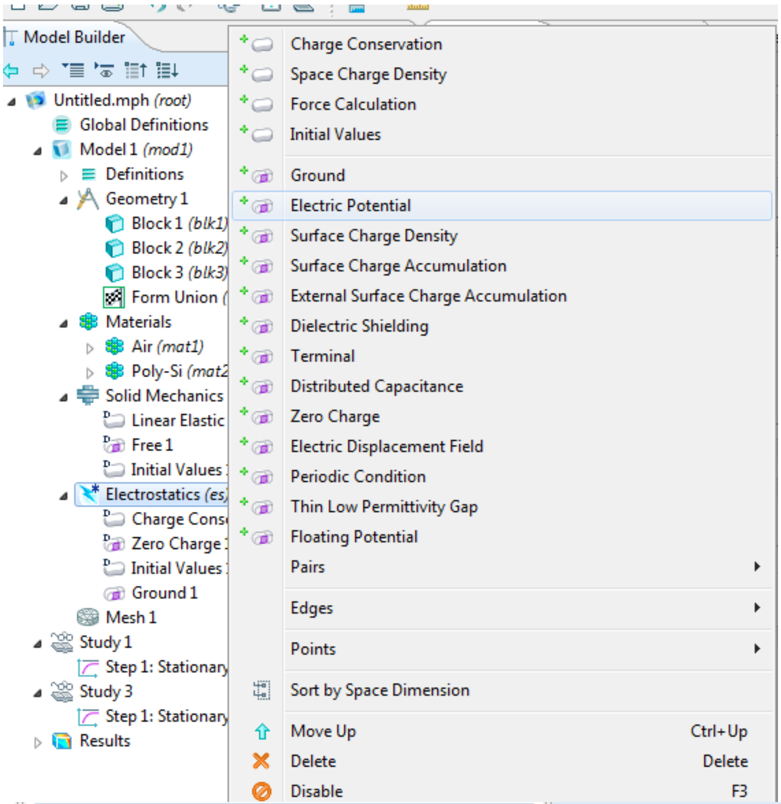

Model Wizard
Model Library
Material Browser
Add Physics
Recently Used
Solid Mechanics (solid)
Electrostatics (es)
Joule Heating (jh)
Joule Heating and Thermal Expansion (tem)
AC/DC
Charged Particle Tracing (cpt)
Electric Currents (ec)
Electric Currents, Shell (ecs)
Electrical Circuit (cir)
Electrostatics (es)
Magnetic Fields (mf)
Magnetic Fields, No Currents (mfnc)
Magnetic and Electric Fields (mef)
Rotating Machinery, Magnetic (rmm)
Acoustics
Chemical Species Transport

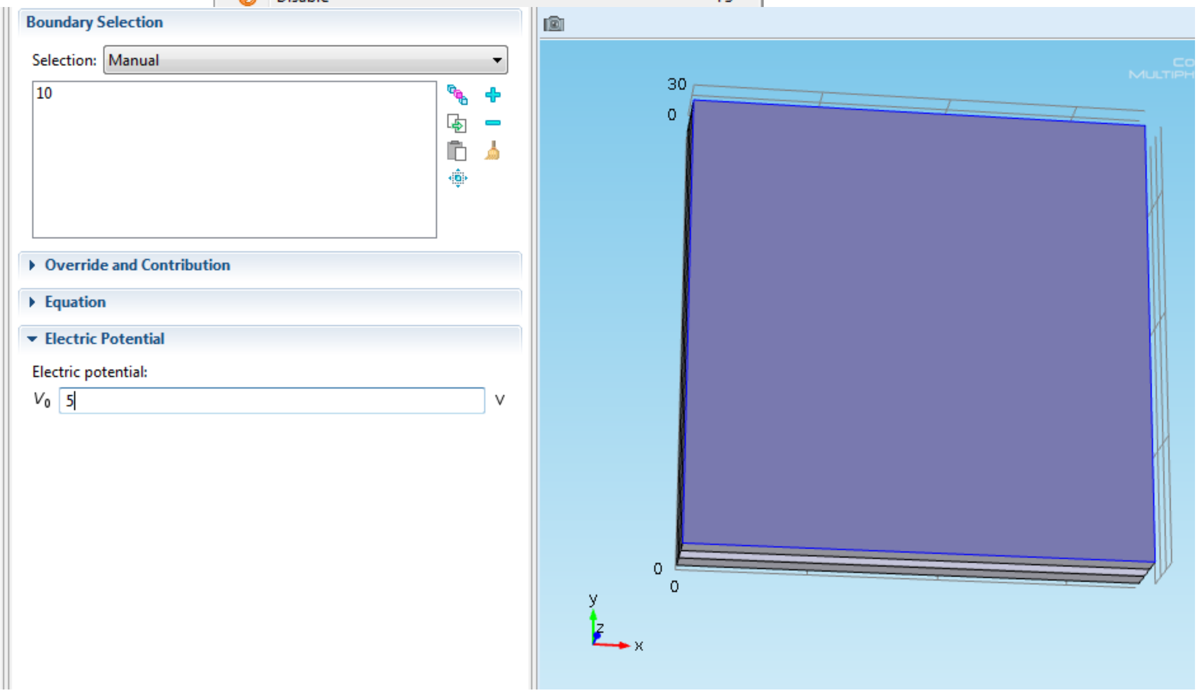


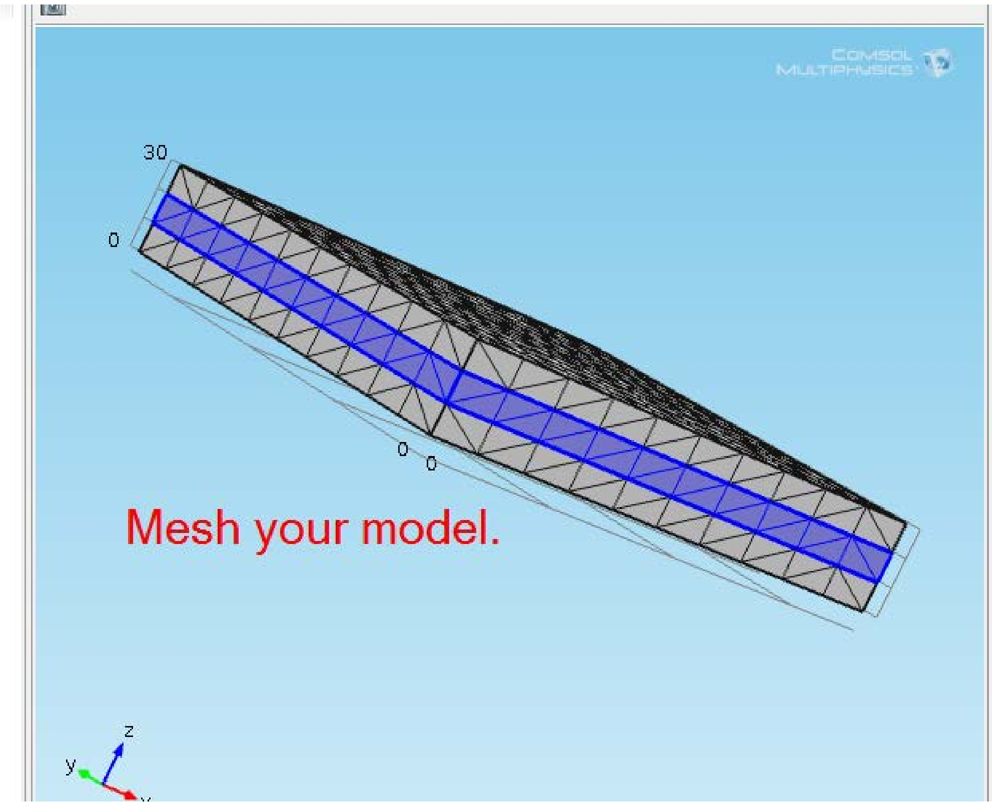


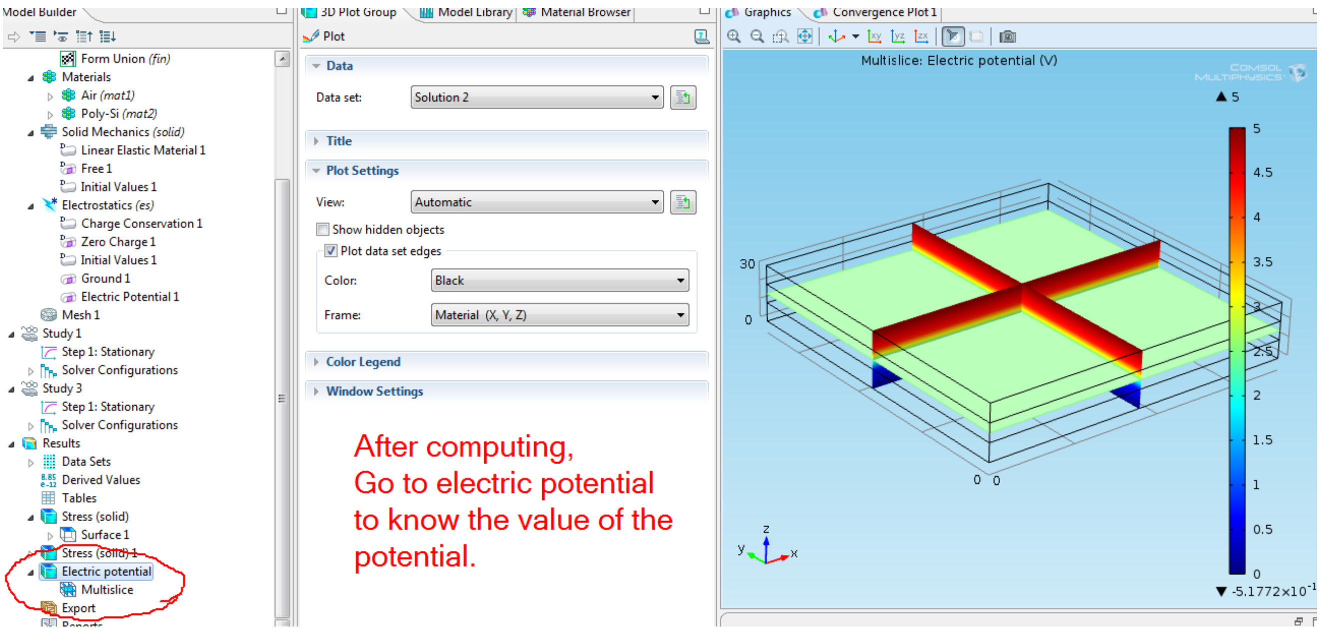
Under electrostatics>
Ground

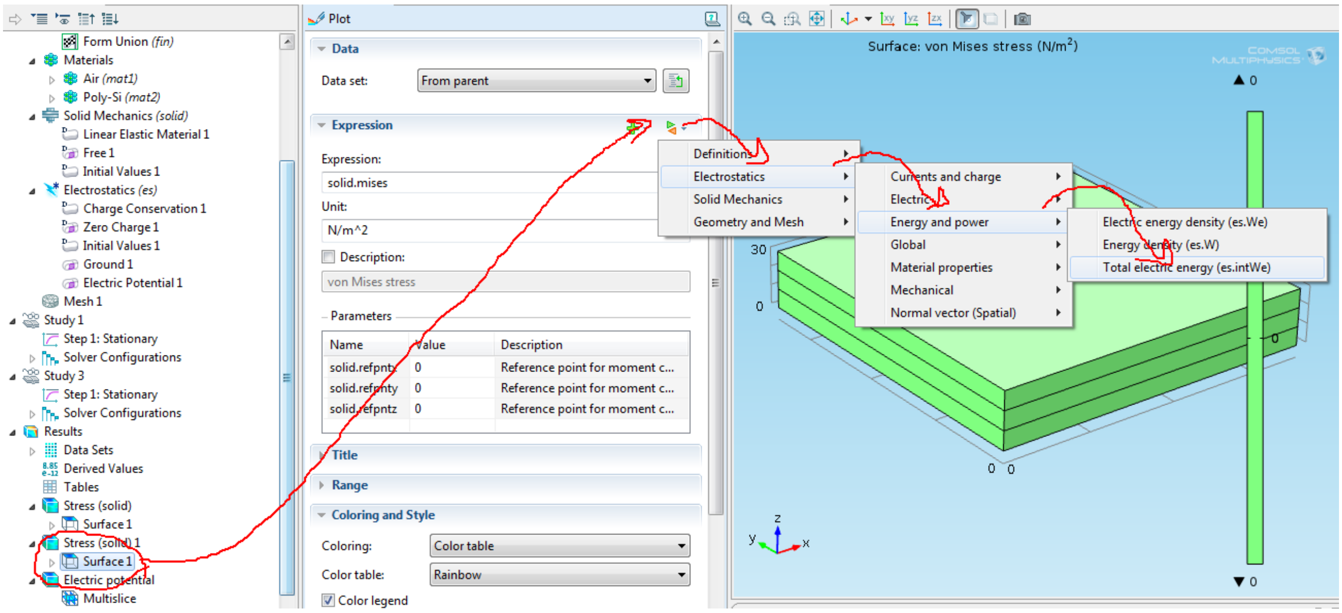
Now, add the lower layer to ground.

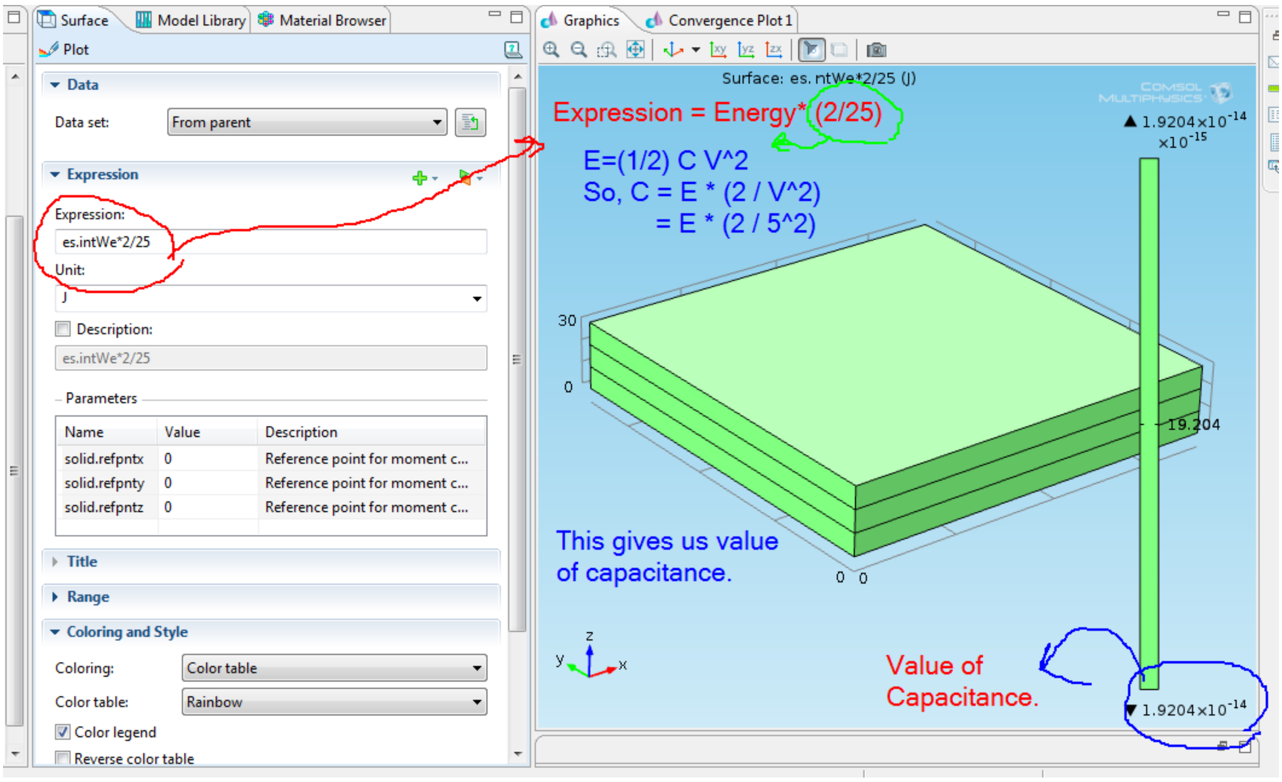

Model Builder
Untitled.mph (root)
Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Block 2 (blk2)
Block 3 (blk3)
Form Union
Materials
Air (mat1)
Poly-Si (mat2
Solid Mechanics
Linear Elastic
Free 1
Initial Values
Electrostatics (es)
Charge Cons
Zero Charge
Initial Values
Ground 1
Mesh 1
Study 1
Step 1: Stationary
Study 3
Step 1: Stationary
Results
Charge Conservation
Space Charge Density
Force Calculation
Initial Values
Ground
Electric Potential
Surface Charge Density
Surface Charge Accumulation
External Surface Charge Accumulation
Dielectric Shielding
Terminal
Distributed Capacitance
Zero Charge
Electric Displacement Field
Periodic Condition
Thin Low Permittivity Gap
Floating Potential
Pairs
Edges
Points
Sort by Space Dimension
Move Up Ctrl+Up
Delete Delete
Disable F3


Boundary Selection
Selection: Manual
10
Override and Contribution
Equation
Electric Potential
Electric potential:
V0 5 V
30
0
0
0
y
z
x

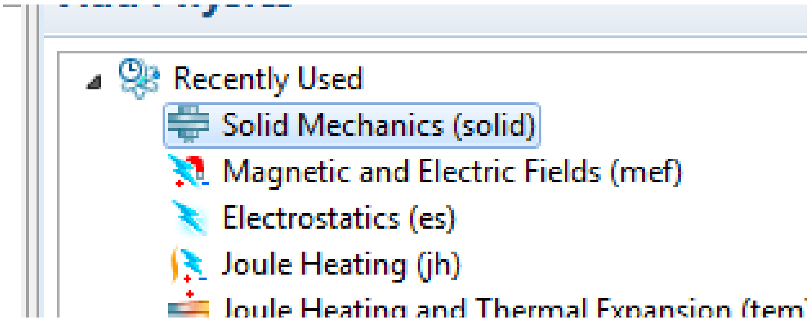

Mesh your model.

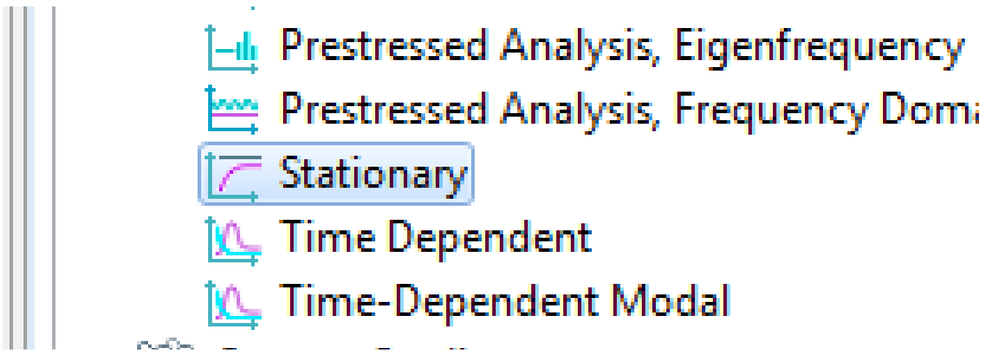

Model Builder
Materials
Air (mat1)
Poly-Si (mat2)
Solid Mechanics (solid)
Linear Elastic Material 1
Free 1
Initial Values 1
Electrostatics (es)
Charge Conservation 1
Zero Charge 1
Initial Values 1
Ground 1
Electric Potential 1
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Study 3
Step 1: Stationary
Solver Configurations
Results
Data Sets
Derived Values
Tables
Stress (solid)
Surface 1
Electric potential
Multislice
Export
Plot
Data
Data set: Solution 2
Title
Plot Settings
View: Automatic
Show hidden objects
Plot data set edges
Color: Black
Frame: Material (X, Y, Z)
Color Legend
Window Settings
After computing,
Go to electric potential
to know the value of the
potential.
Multislice: Electric potential (V)

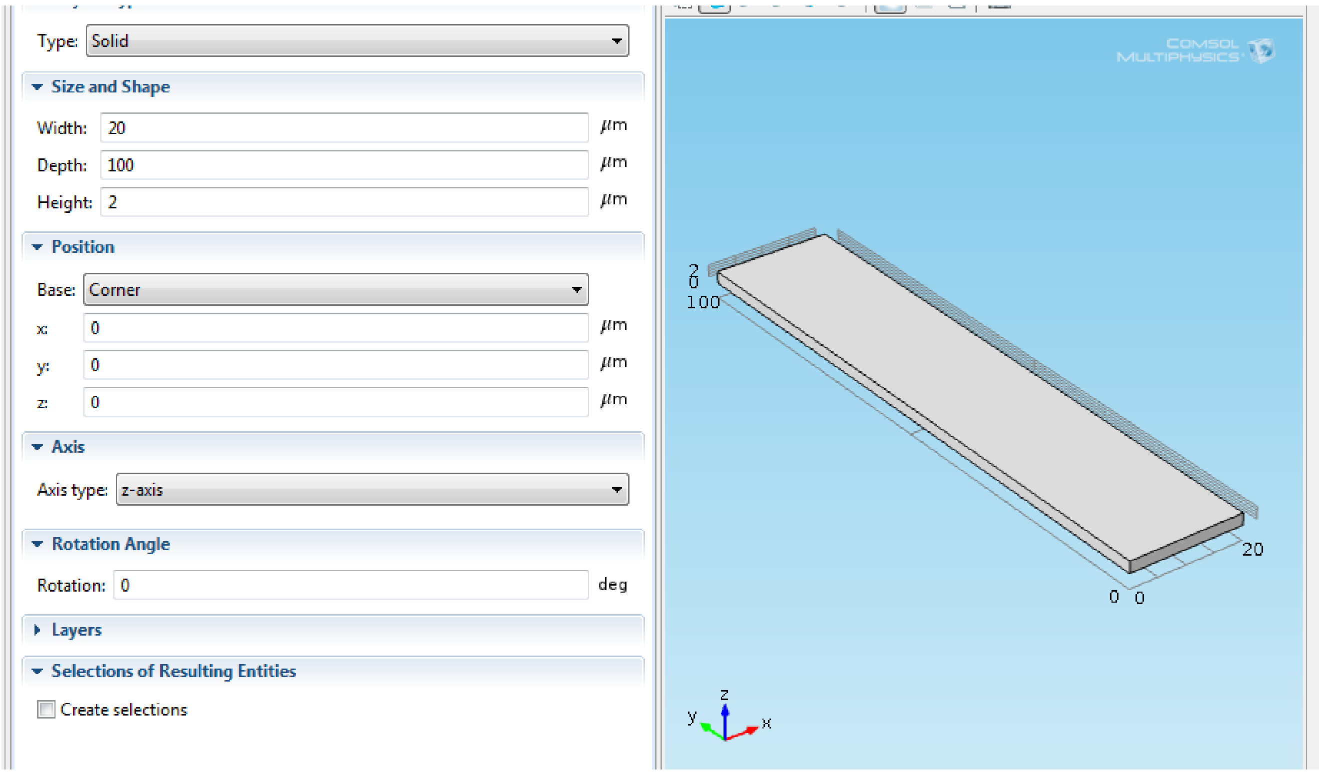

Surface: von Mises stress (N/m²)
Expression:
solid.mises
Definitions
Electrostatics
Solid Mechanics
Geometry and Mesh
Currents and charge
Electric
Energy and power
Global
Material properties
Mechanical
Normal vector (Spatial)
Electric energy density (es.We)
Energy density (es.W)
Total electric energy (es.intWe)

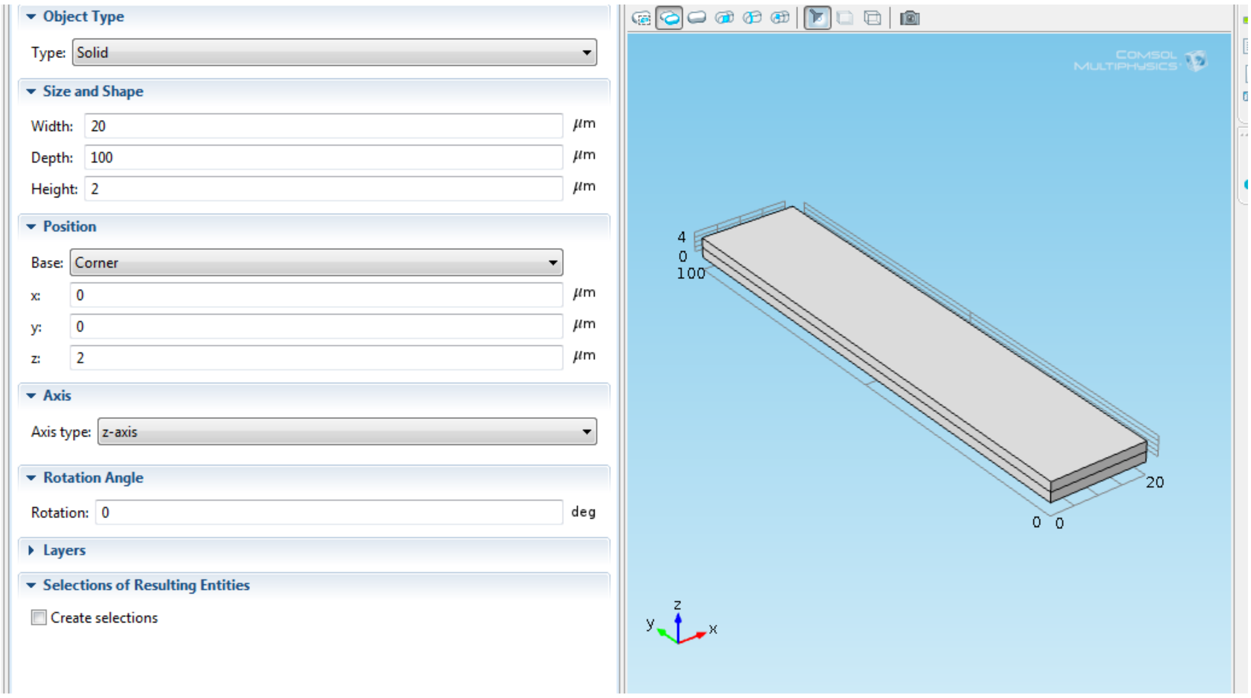

Surface: es.intWe*2/25 (J)
Expression:
es.intWe*2/25
Unit:
J
Expression = Energy*(2/25)
E=(1/2) C V^2
So, C = E * (2 / V^2)
= E * (2 / 5^2)
This gives us value of capacitance.
Value of Capacitance.
1.9204x10^-14

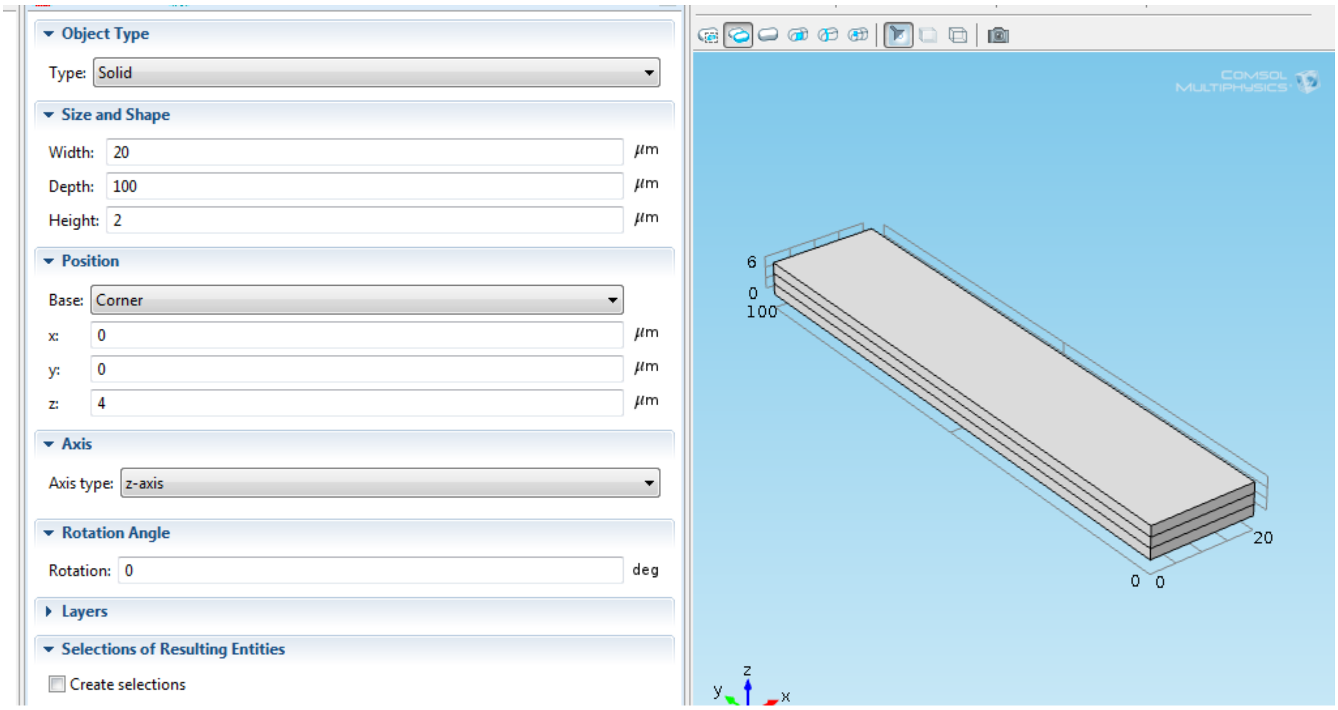
Microgripper

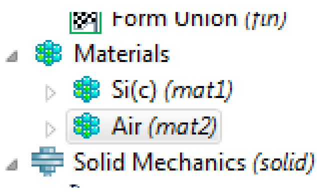


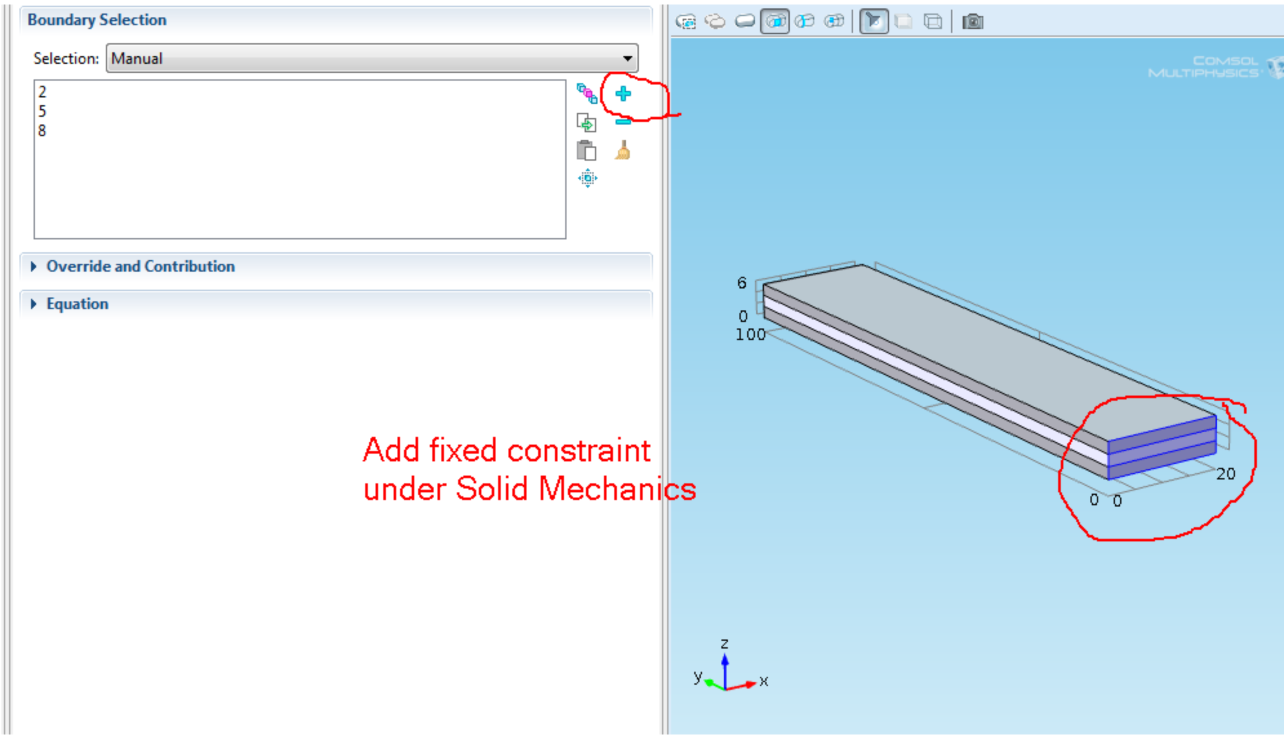


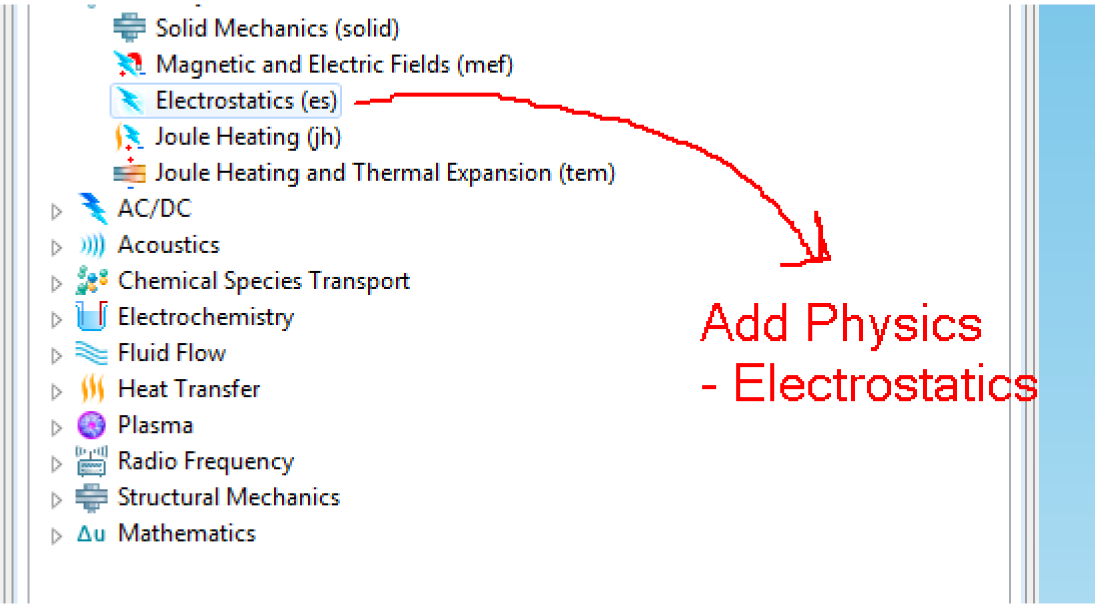


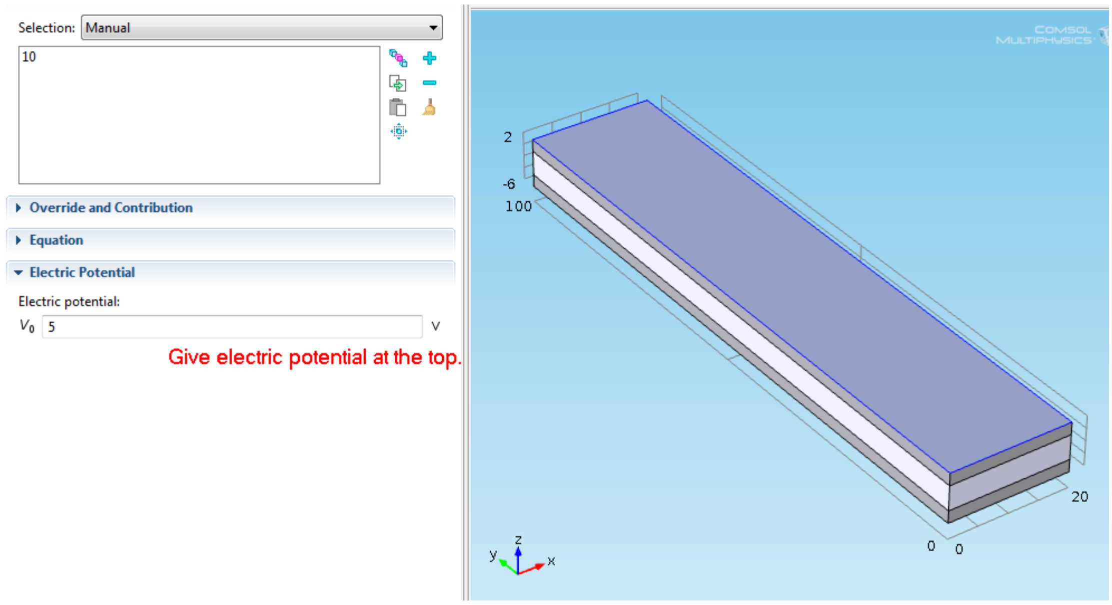

Object Type
Type: Solid
Size and Shape
Width: 20 µm
Depth: 100 µm
Height: 2 µm
Position
Base: Corner
x: 0 µm
y: 0 µm
z: 2 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities
Create selections
4
0
100
20
0 0
z
y
x

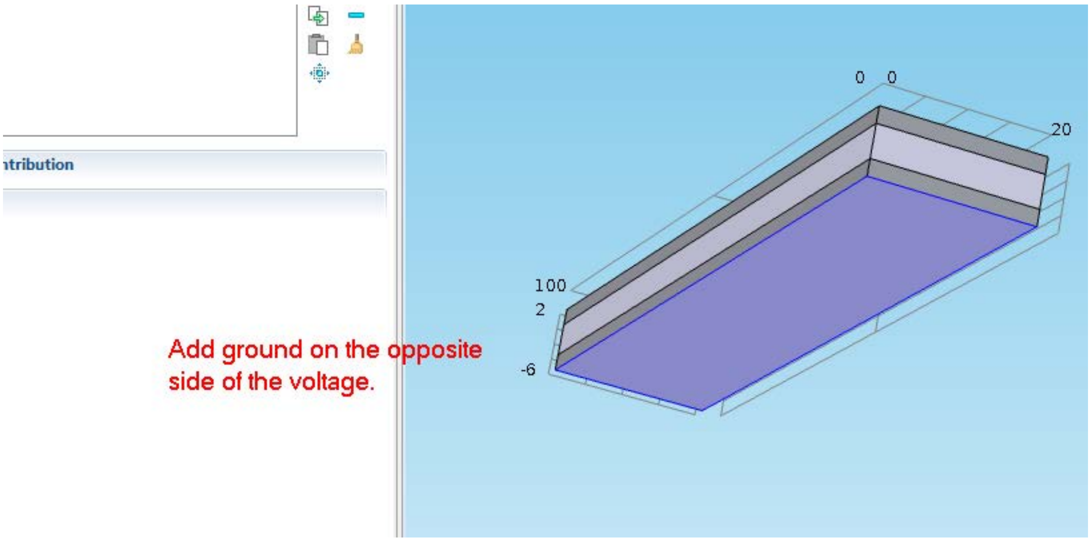

Object Type
Type: Solid
Size and Shape
Width: 20 µm
Depth: 100 µm
Height: 2 µm
Position
Base: Corner
x: 0 µm
y: 0 µm
z: 4 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities
Create selections
6
0
100
20
0 0
z
y
x

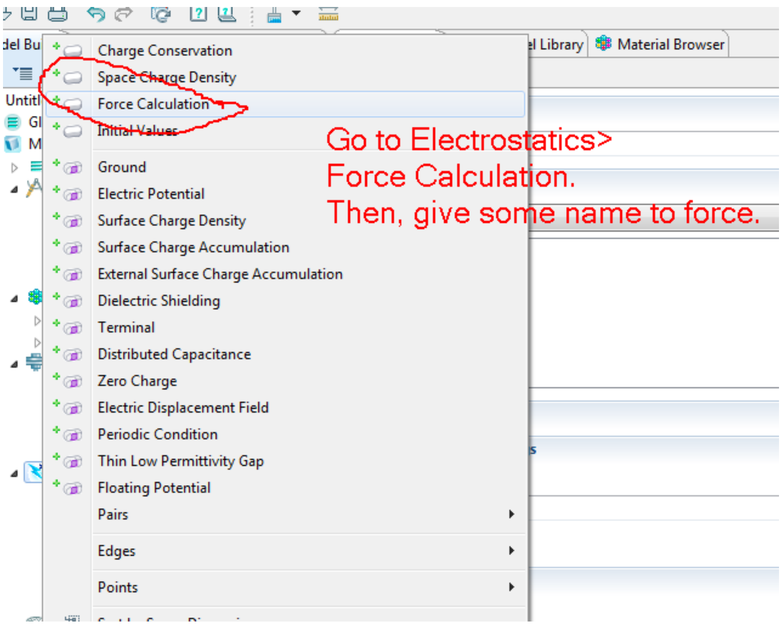

Form Union (fin)
Materials
Si(c) (mat1)
Air (mat2)
Solid Mechanics (solid)

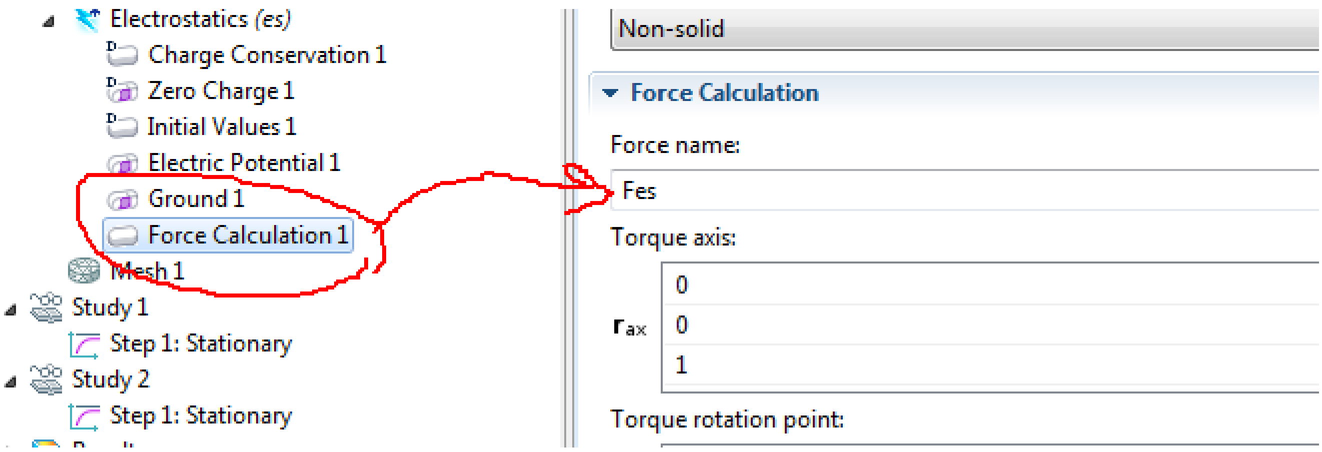

Boundary Selection
Selection: Manual
2
5
8
Override and Contribution
Equation
Add fixed constraint
under Solid Mechanics


Solid Mechanics (solid)
Magnetic and Electric Fields (mef)
Electrostatics (es)
Joule Heating (jh)
Joule Heating and Thermal Expansion (tem)
AC/DC
Acoustics
Chemical Species Transport
Electrochemistry
Fluid Flow
Heat Transfer
Plasma
Radio Frequency
Structural Mechanics
Mathematics
Add Physics
- Electrostatics

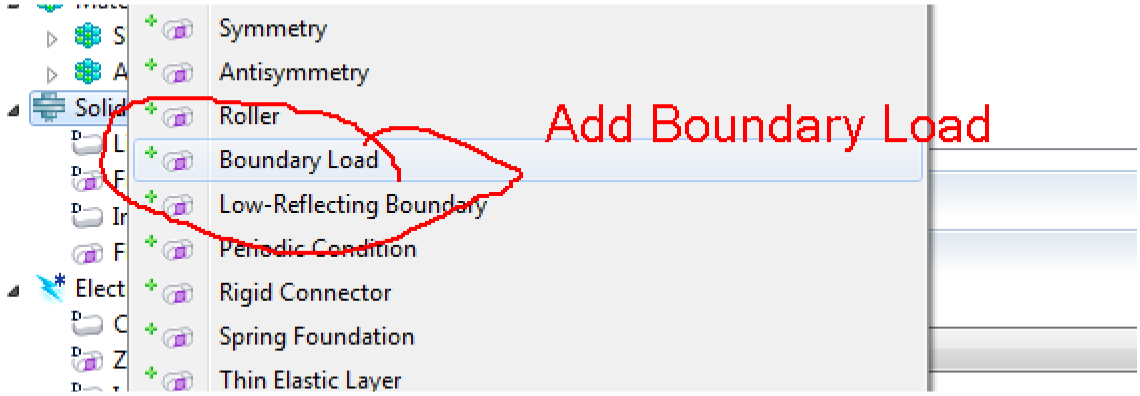

Selection: Manual
10
Override and Contribution
Equation
Electric Potential
Electric potential:
V_0 5 V
Give electric potential at the top.
2
-6
100
20
0 0

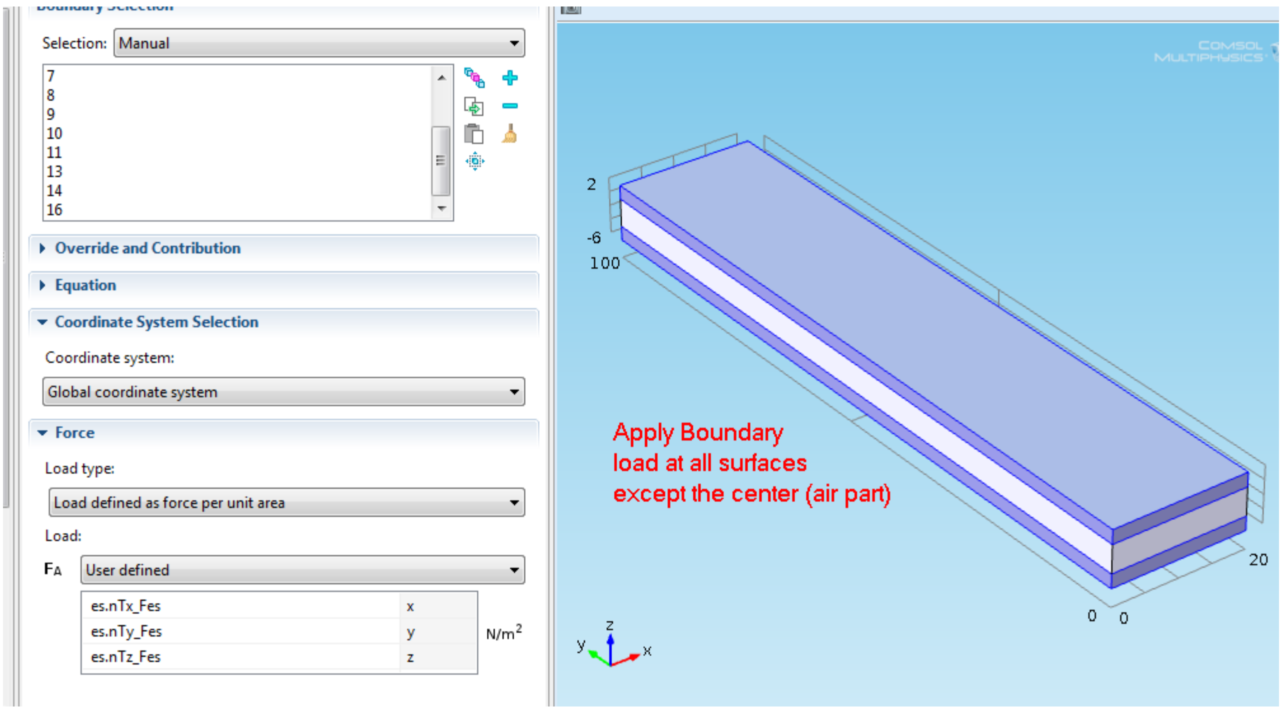

ntribution
Add ground on the opposite side of the voltage.
0 0
20
100
2
-6

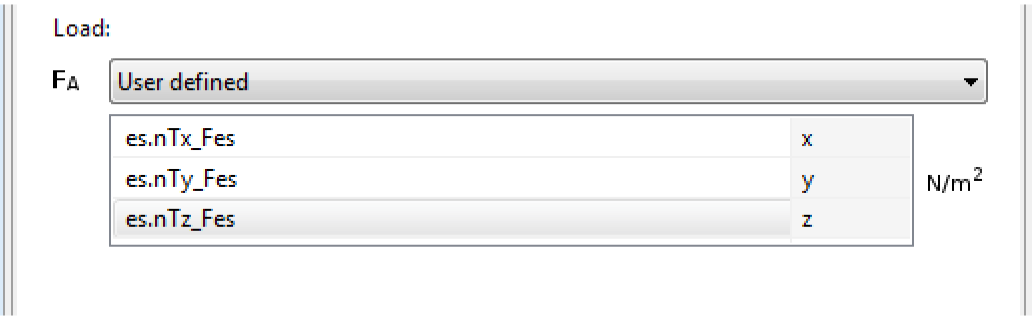

Charge Conservation
Space Charge Density
Force Calculation
Initial Values
Ground
Electric Potential
Surface Charge Density
Surface Charge Accumulation
External Surface Charge Accumulation
Dielectric Shielding
Terminal
Distributed Capacitance
Zero Charge
Electric Displacement Field
Periodic Condition
Thin Low Permittivity Gap
Floating Potential
Pairs
Edges
Points
Material Browser
Go to Electrostatics> Force Calculation.
Then, give some name to force.

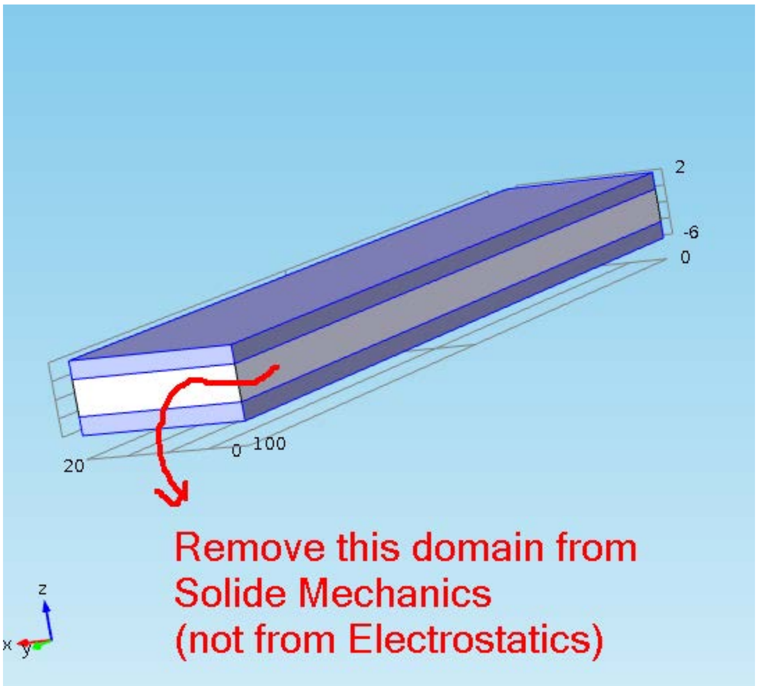


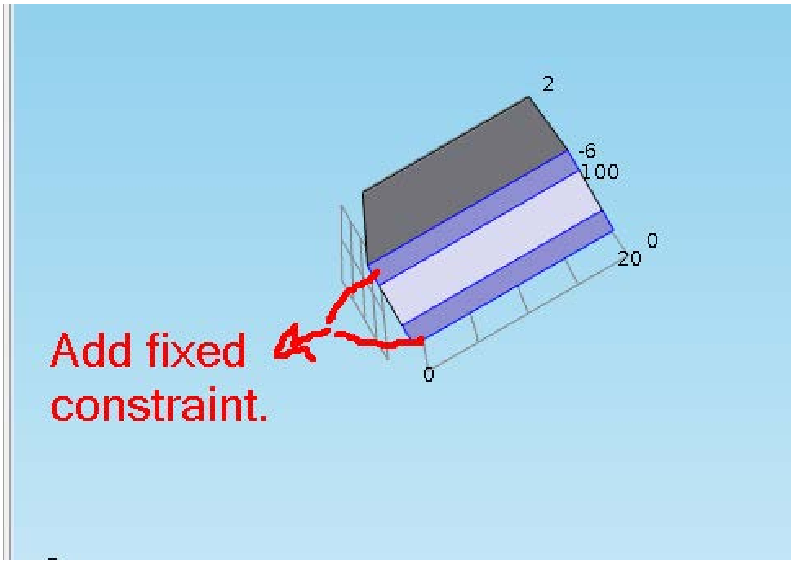
Note: Force also has to be given only at the top and bottom. Not in the middle.

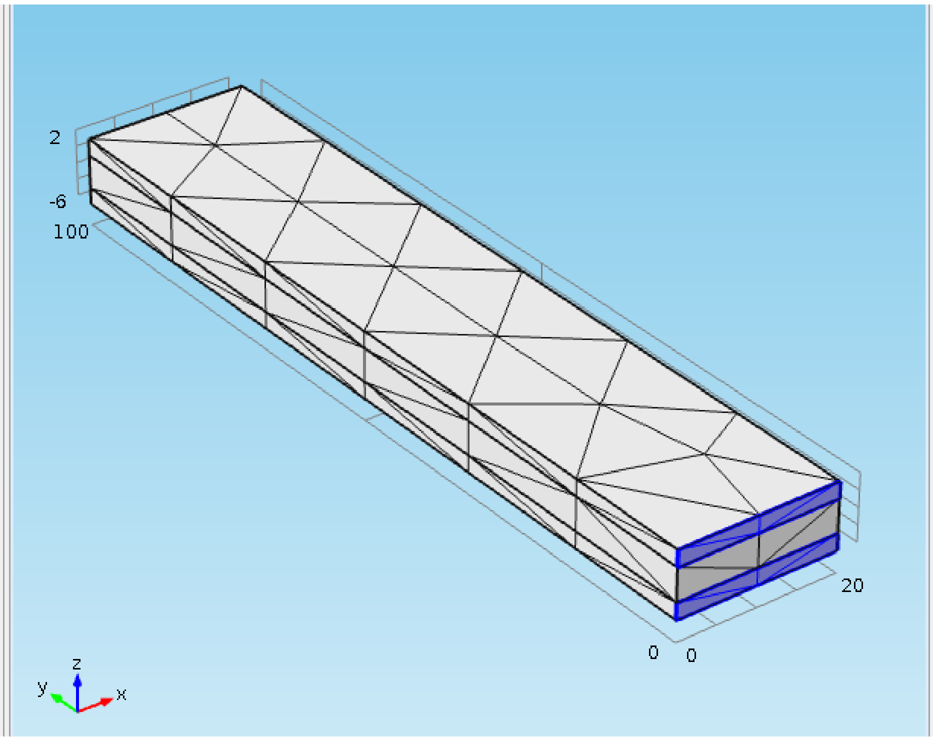




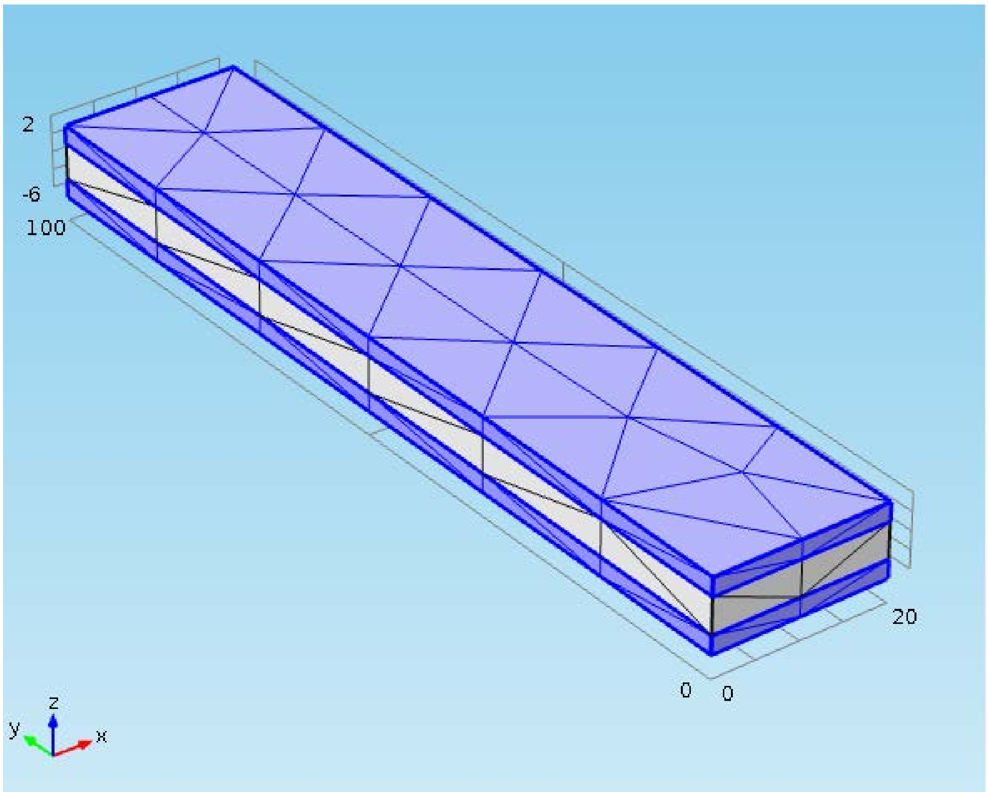

Load:
FA
User defined
es.nTx_Fes
x
es.nTy_Fes
y
es.nTz_Fes
z
N/m2

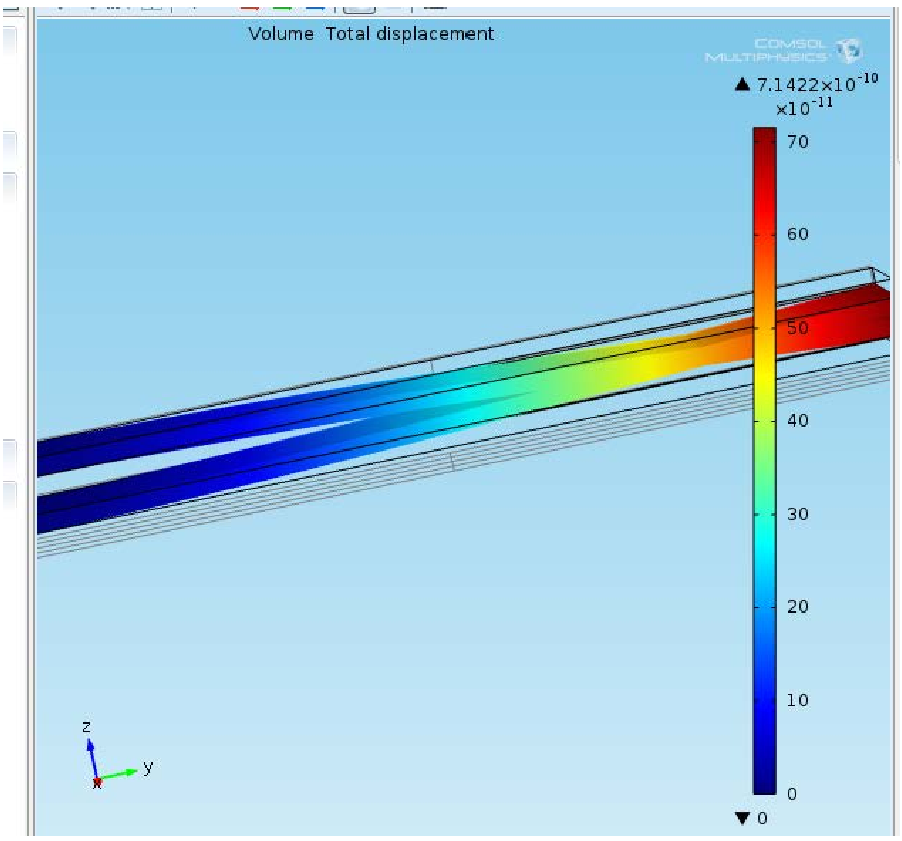

2
-6
0
20
0
100
Remove this domain from
Solide Mechanics
(not from Electrostatics)
z
x
y

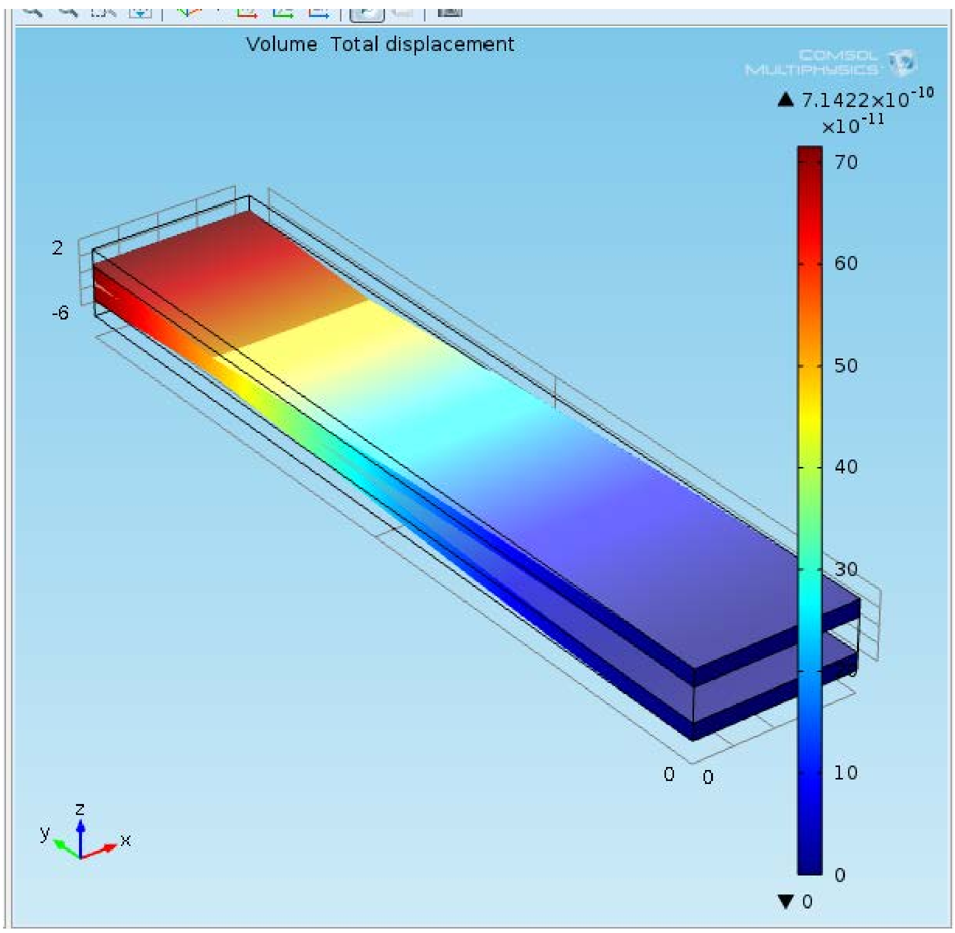

2
-6
100
0
20
0
Add fixed
constraint.

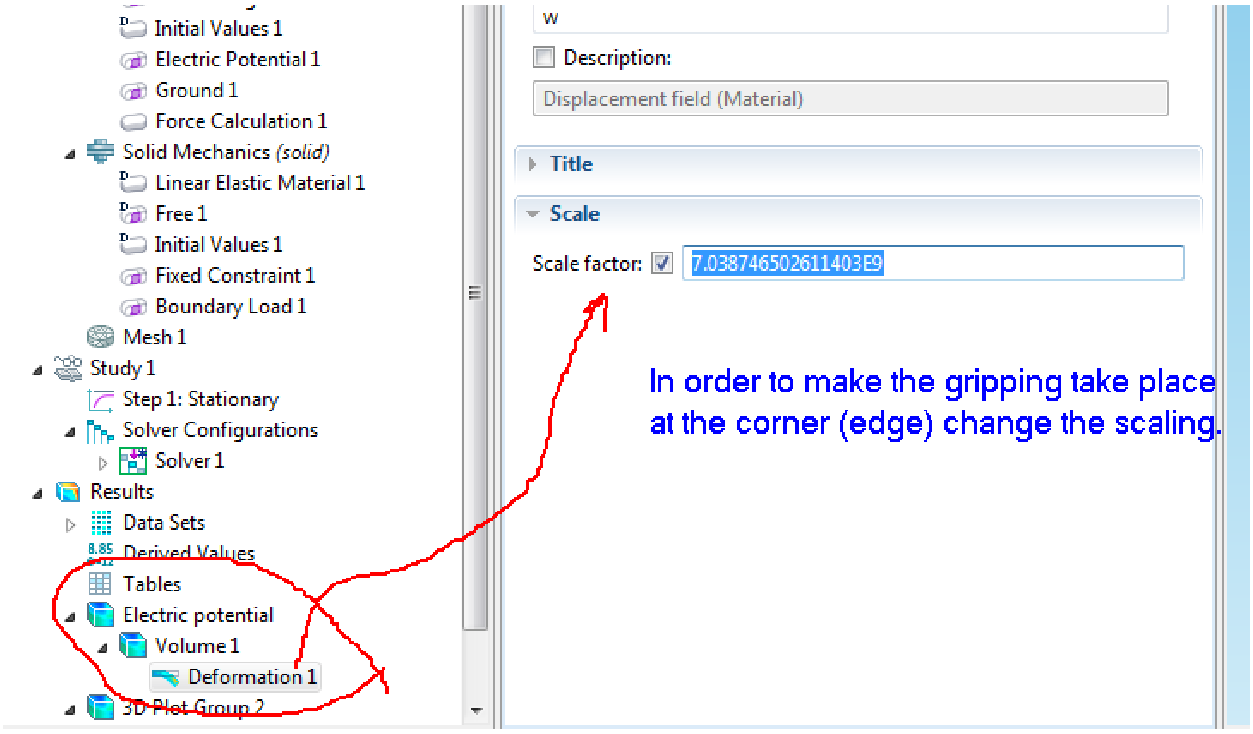


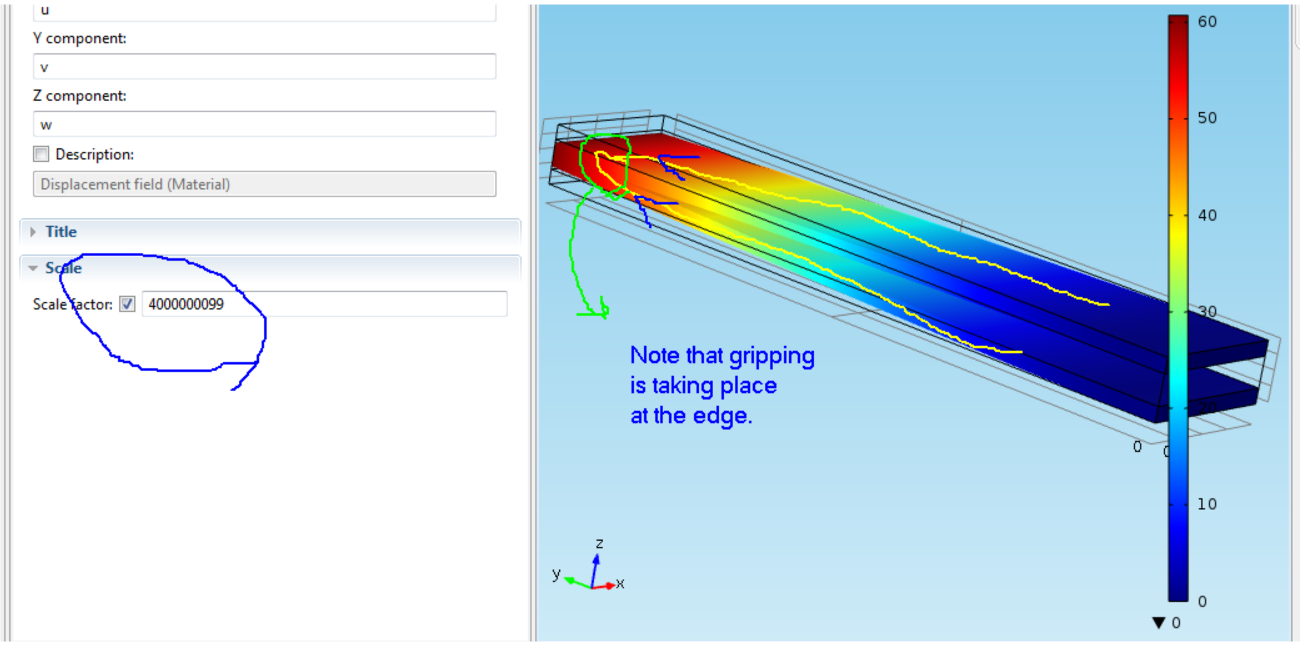
In Force calculation, the force has to be added in the specified part:




Volume Total displacement
▲ 7.1422×10^-10
×10^-11
70
60
50
40
30
20
10
0
▼ 0
z
y


Volume Total displacement
▲ 7.1422×10^-10
×10^-11
70
60
50
40
30
10
0
▼ 0
2
-6
0
0
z
y
x


Initial Values 1
Electric Potential 1
Ground 1
Force Calculation 1
Solid Mechanics (solid)
Linear Elastic Material 1
Free 1
Initial Values 1
Fixed Constraint 1
Boundary Load 1
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Solver 1
Results
Data Sets
Derived Values
Tables
Electric potential
Volume 1
Deformation 1
3D Plot Group 2
w
Description:
Displacement field (Material)
Title
Scale
Scale factor:
7.0387465026114O3E9
In order to make the gripping take place at the corner (edge) change the scaling.


u
Y component:
v
Z component:
w
Description:
Displacement field (Material)
Title
Scale
Scale factor:
4000000099
Note that gripping is taking place at the edge.
60
50
40
30
10
0
▼ 0
z
y
x

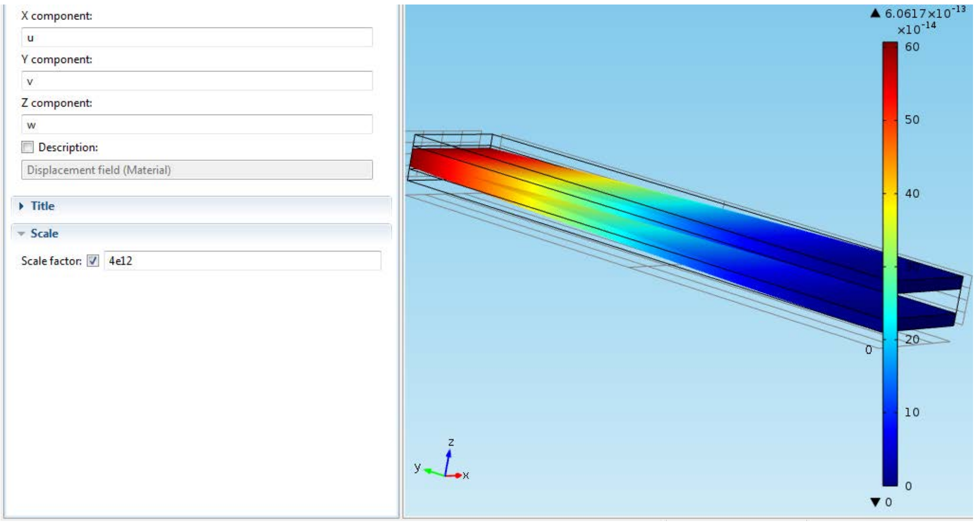
MICROGRIPPER: Scale Changing

Micro gripper was used in Micro scale.
Now, change it to different scales and measure the difference in deflection.
We see that the only change needs to be done in the scaling factor.
The scaling needs to be increased to see the same effect of gripping.

Original Scale : um

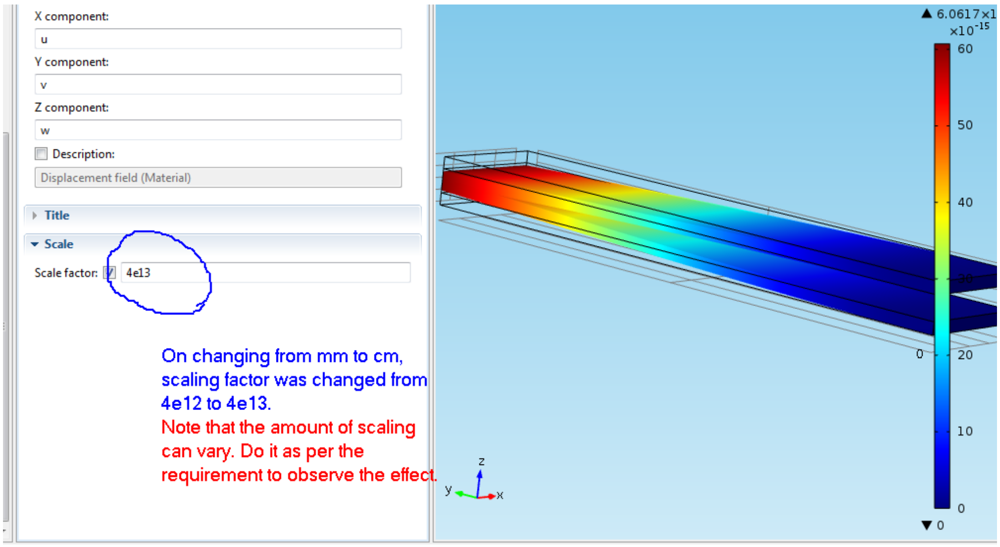
Case 1:

Changing scale to mm



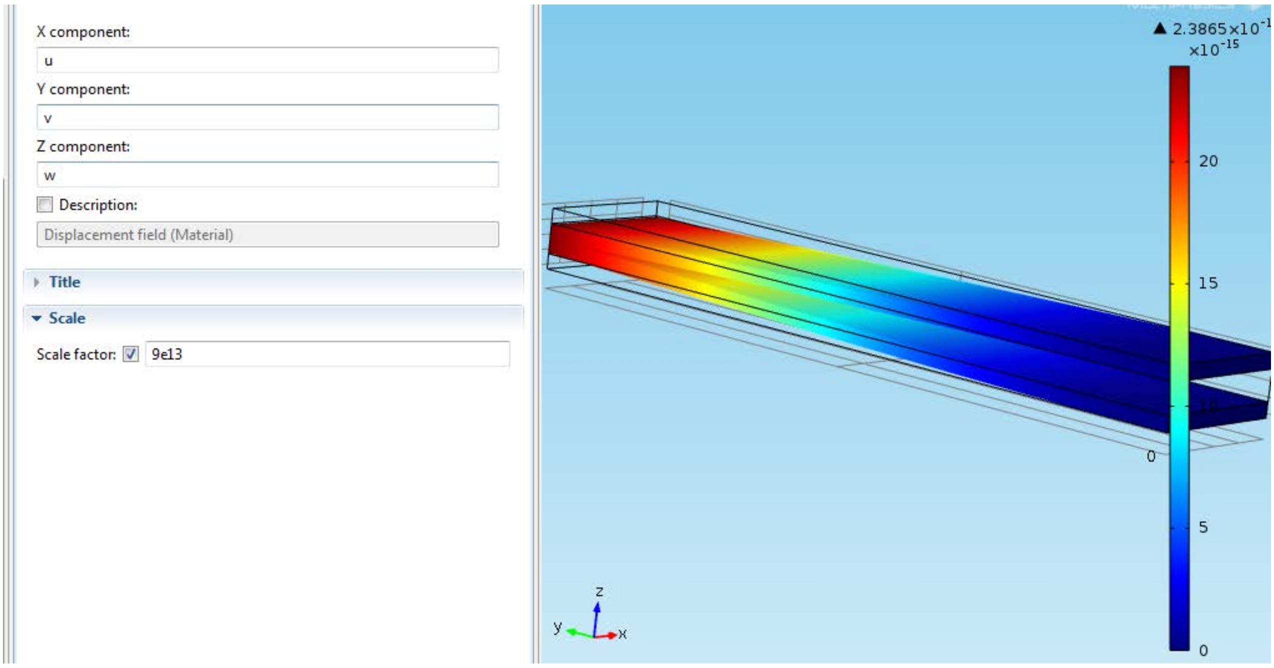
Case 2:

Changing the scale to cm



Case 3:

Changing scale to inch



Note: Displacement is independent of scaling.

OBSERVATION 1:

Constant:

- Material - Si (c)

Table 1: Shows the amount of scaling that needs to be done in order to get the gripping action at the corner.

Dimension	Scaling	Displacement (m)
Mm	4e12	6.0617*10^-13
Cm	4e13	6.0614*10^-14
In	9e13	2.3865*10^-14

OBSERVATION 2:

Now, keeping um as standard displacement, changing the values of voltage to get the same displacement at other scales.

Constant:

- Material: Silicon
- Reference - um
  - Scaling - 4e9
  - Displacement - 6.0617*10^-10 m

Table 2: Shows the value of the voltage for each scale, giving the same displacement as in micrometer scale.

Dimension	Displacement (m)	Voltage value (V)
Mm	6.0617*10^-13	5
	6.0617*10^-11	50
	1.3639*10^-10	75
	6.053*10^-10	158
Cm	6.0614*10^-14	5
	6.0617*10^-12	50
	5.455*10^-11	150
	6.0617*10^-10	500
In	2.3865*10^-14	5
	9.546*10^-12	100
	8.5914*10^-11	300
	6.03333*10^-10	795

OBSERVATION 3:

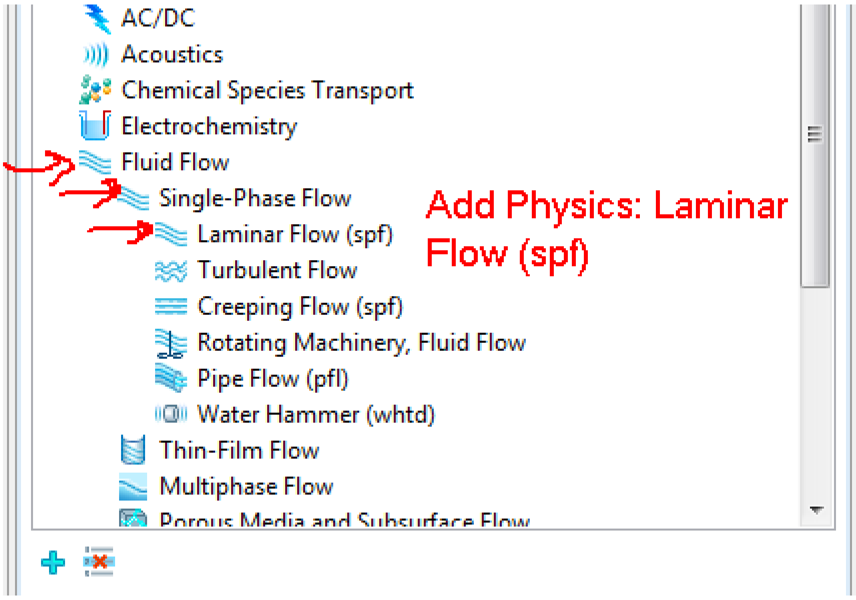
Now changing the material of the micro gripper and observing the displacement.
Constant:

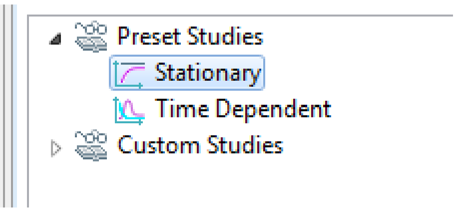
- Dimension: um
- Middle layer: Air

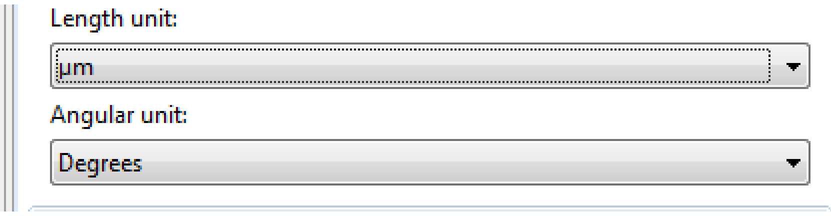
Table 3: Shows the displacement of the micro gripper with different materials.

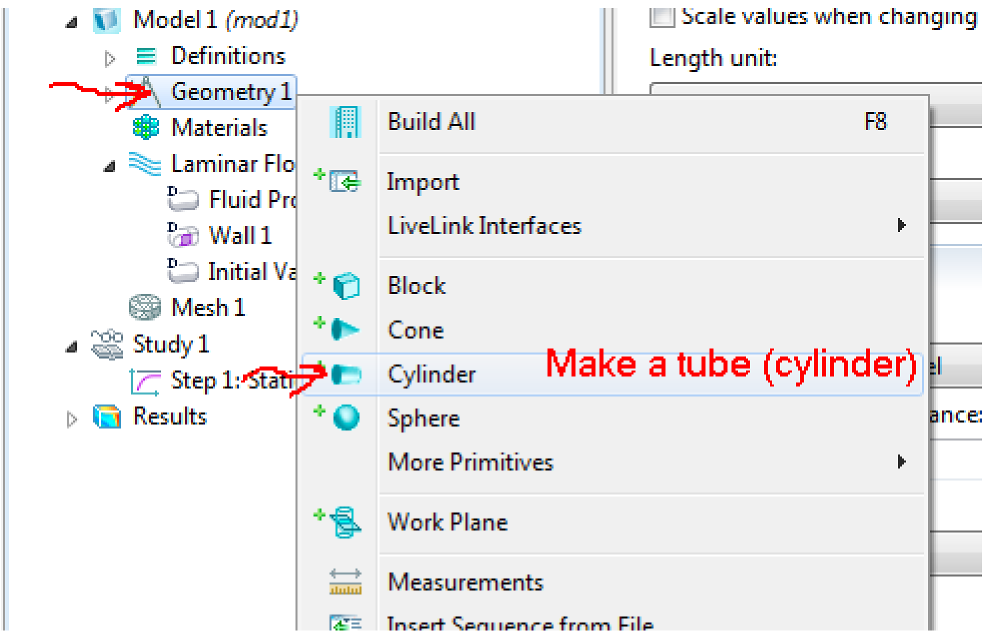
Material	Displacement (m)
Si (c)	6.0617*10^-10
Poly-Si	5.1787*10^-10
Glass (quartz)	1.0616*10^-9
GaAs	1.189*10^-9
SiO2	1.1665*10^-9

Scaling Problem: **We have a cylinder (tube) and fluid flowing through it. Now, when the dimensions of the tube is changed, note the pressure drop.**

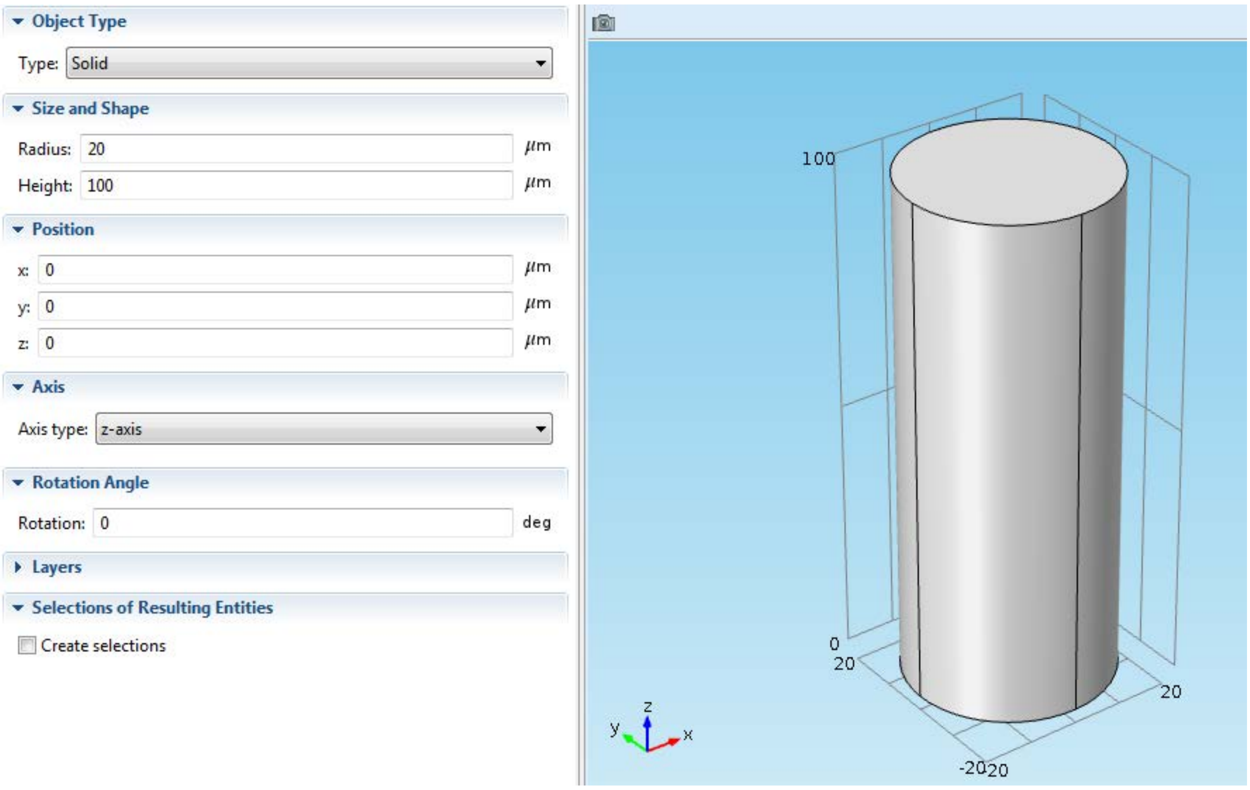




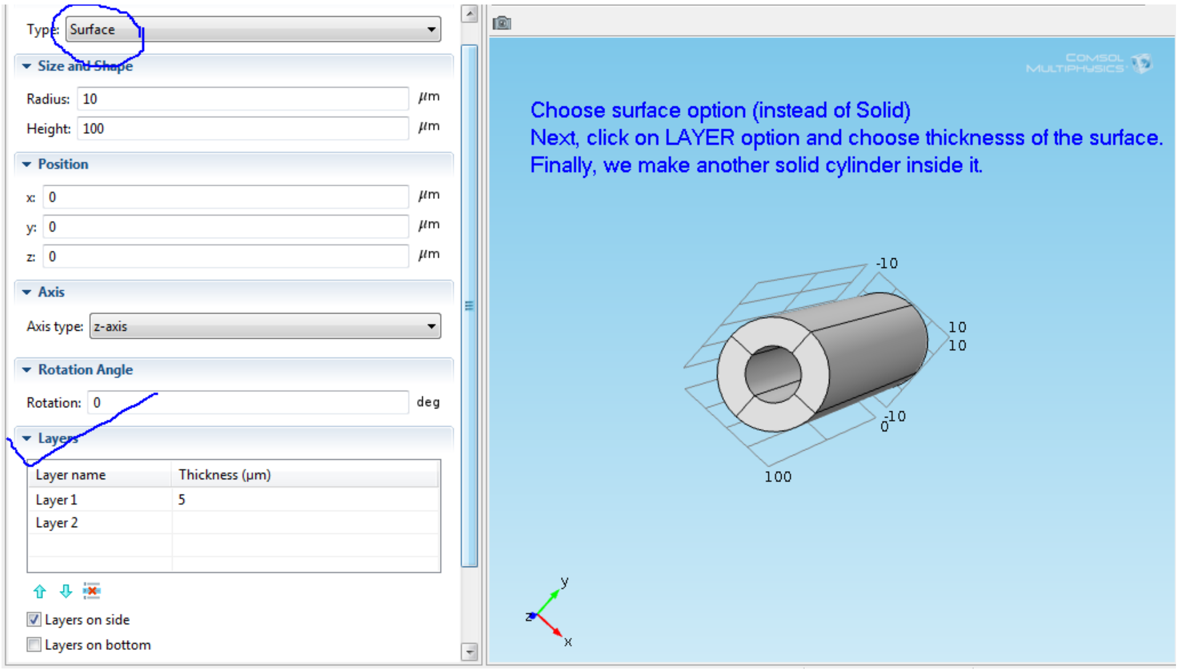




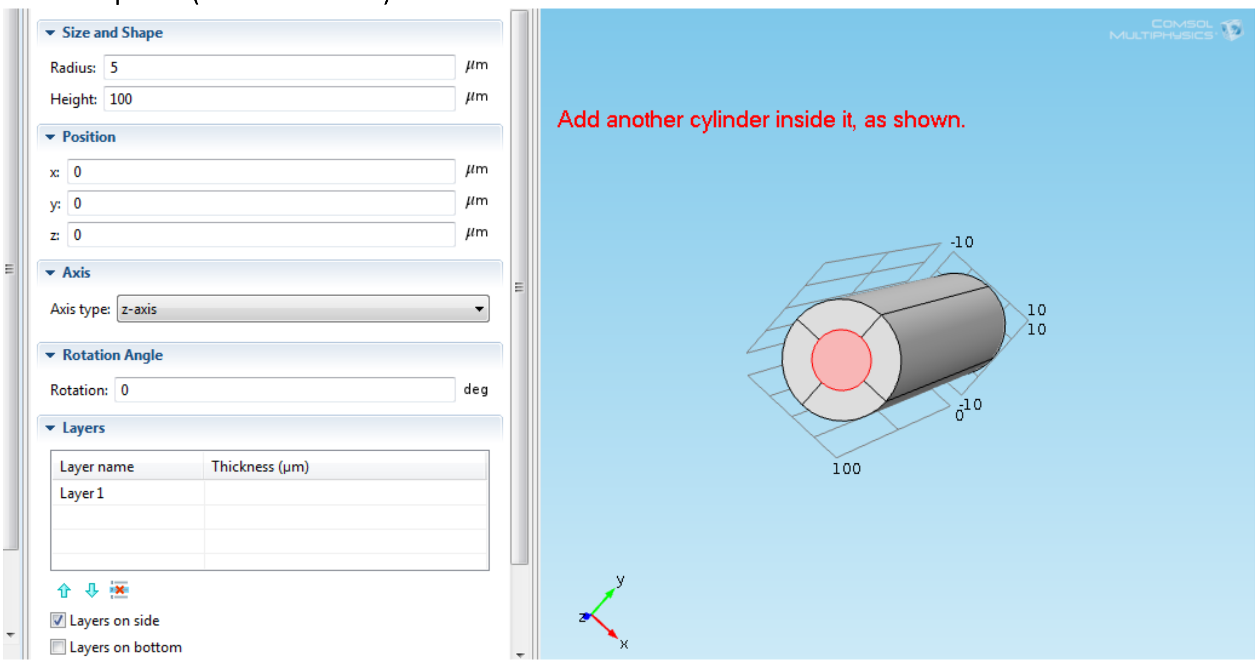
Model 1 (mod1)
Definitions
Geometry 1
Materials
Laminar Flo
Fluid Pro
Wall 1
Initial Va
Mesh 1
Study 1
Step 1: Stati
Results
Scale values when changing
Length unit:
Build All
F8
Import
LiveLink Interfaces
Block
Cone
Cylinder
Make a tube (cylinder)
Sphere
More Primitives
Work Plane
Measurements
Insert Sequence from File

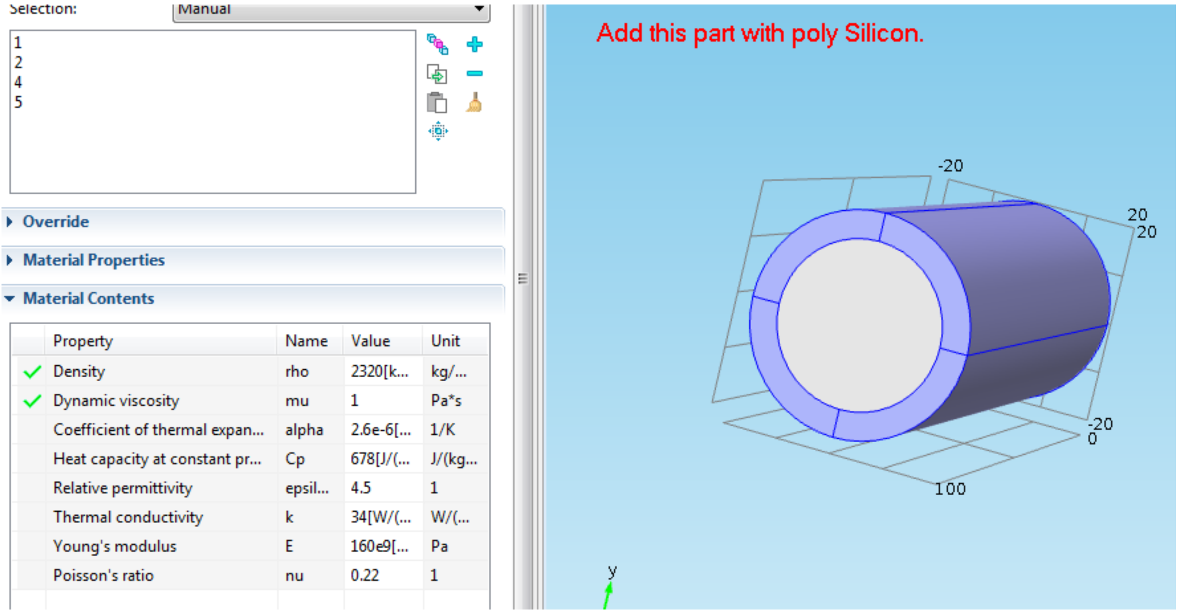


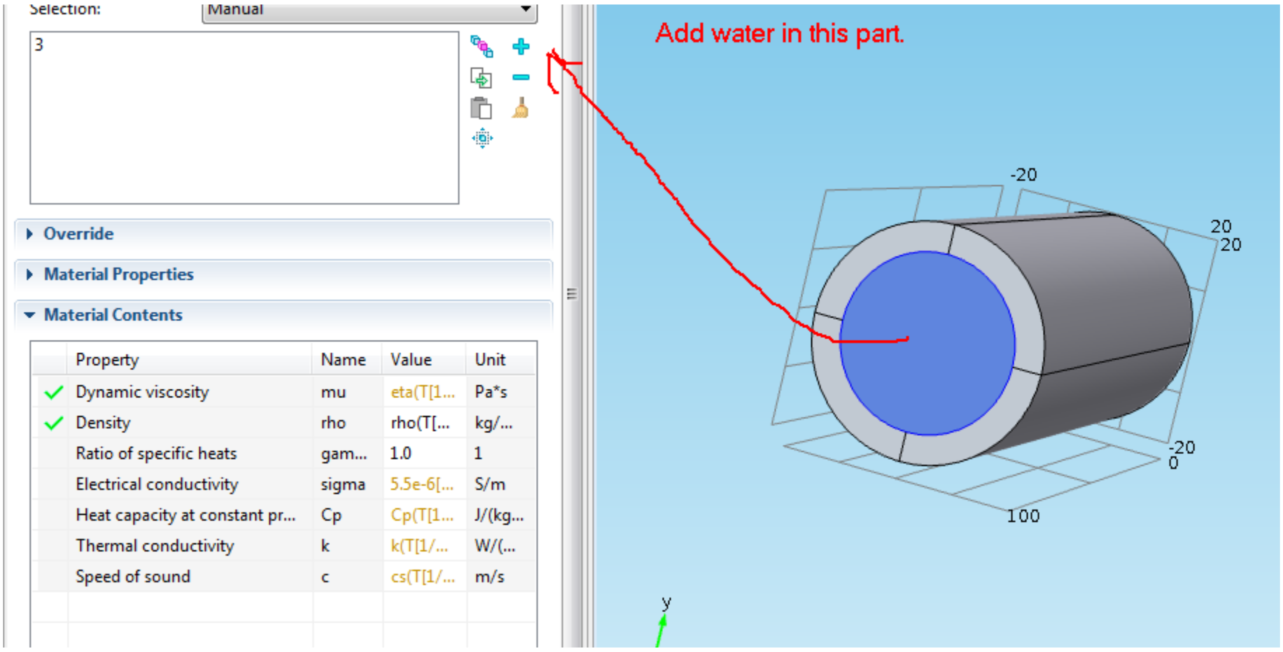
Object Type
Type: Solid
Size and Shape
Radius: 20 µm
Height: 100 µm
Position
x: 0 µm
y: 0 µm
z: 0 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities
Create selections
100
0
20
20
-20
20
z
y
x

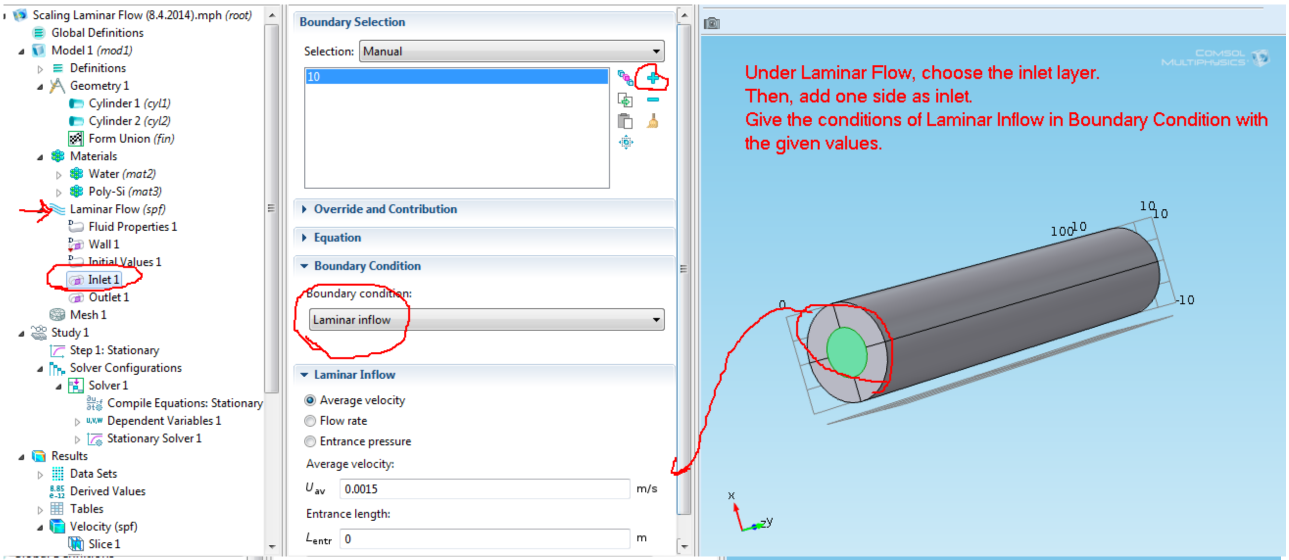


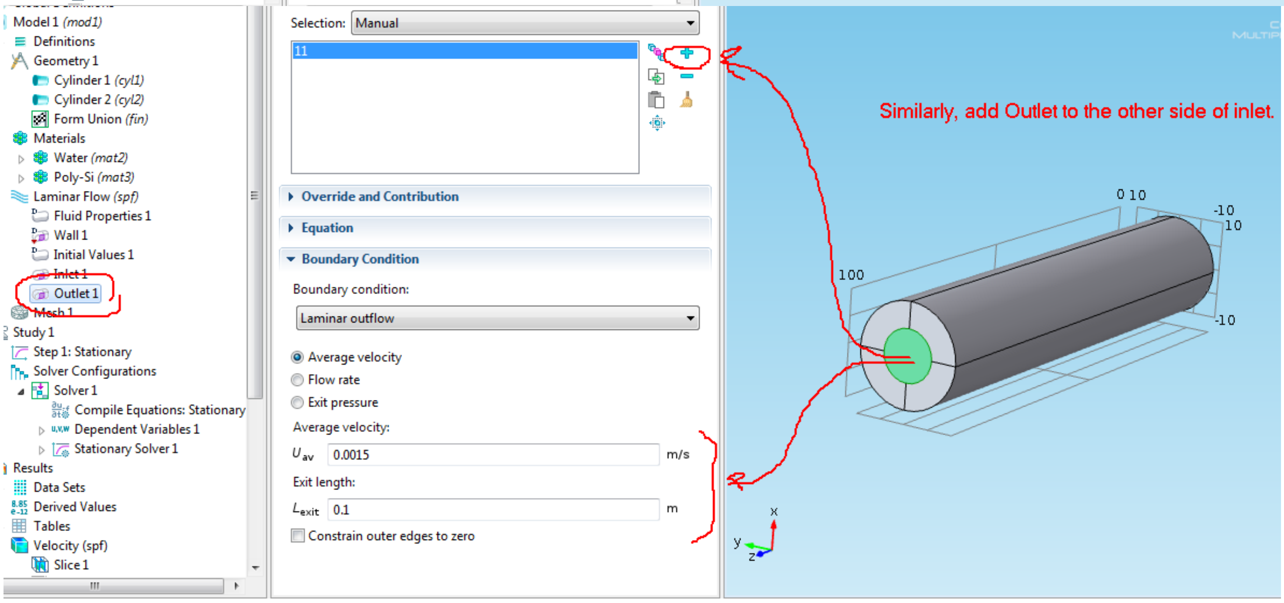
Surface option. (instead of Solid)

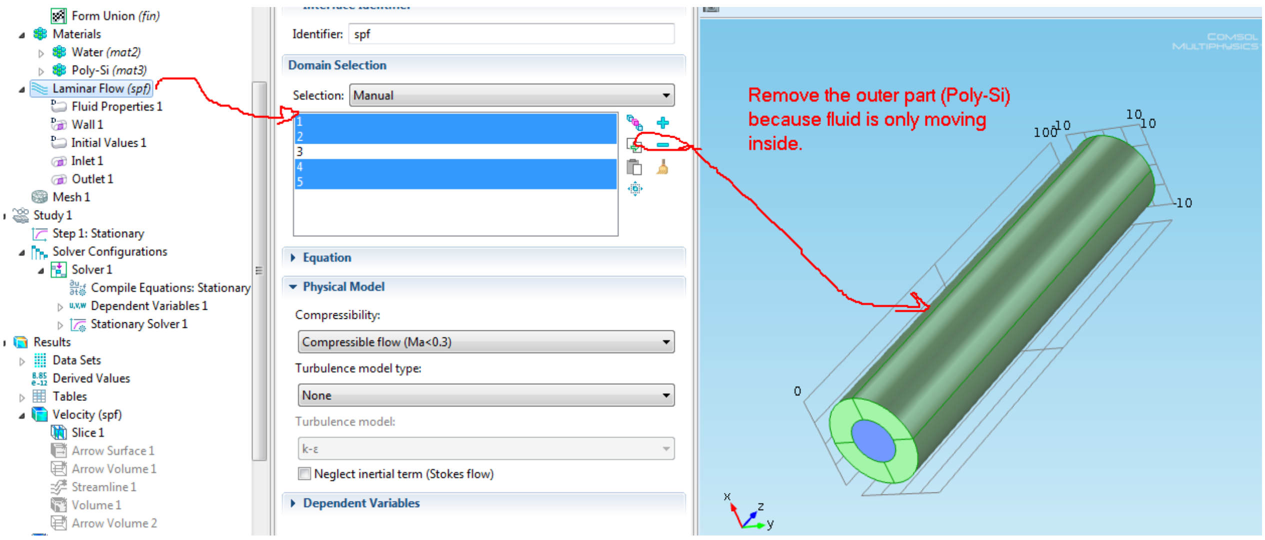


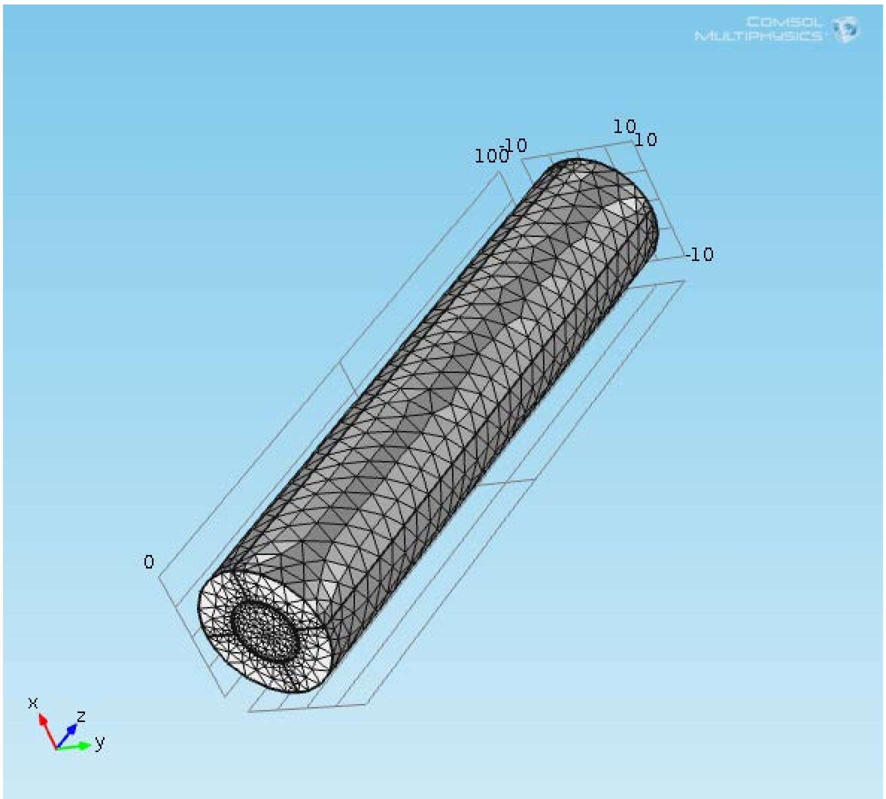

Selection:
Manual
1
2
4
5
Override
Material Properties
Material Contents
Property Name Value Unit
Density rho 2320[k... kg/...
Dynamic viscosity mu 1 Pa*s
Coefficient of thermal expan... alpha 2.6e-6[... 1/K
Heat capacity at constant pr... Cp 678[J/(... J/(kg...
Relative permittivity epsil... 4.5 1
Thermal conductivity k 34[W/(... W/(...
Young's modulus E 160e9[... Pa
Poisson's ratio nu 0.22 1
Add this part with poly Silicon.
-20
20
20
-20
0
100
y


Selection:
Manual
3
Override
Material Properties
Material Contents
Property Name Value Unit
Dynamic viscosity mu eta(T[1... Pa*s
Density rho rho(T[... kg/...
Ratio of specific heats gam... 1.0 1
Electrical conductivity sigma 5.5e-6[... S/m
Heat capacity at constant pr... Cp Cp(T[1... J/(kg...
Thermal conductivity k k(T[1/... W/(...
Speed of sound c cs(T[1/... m/s
Add water in this part.
-20
20
20
-20
0
100
y

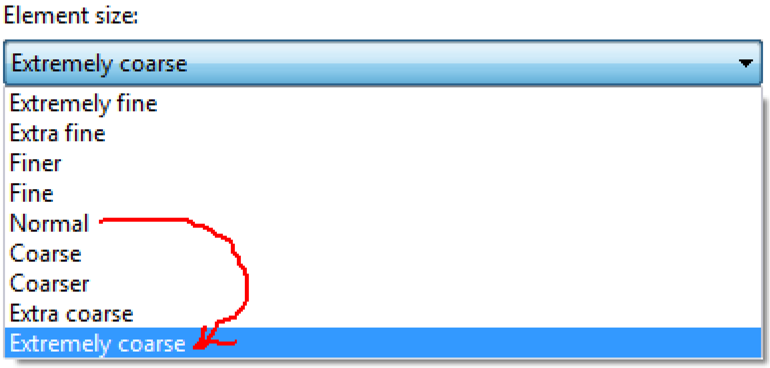

Under Laminar Flow, choose the inlet layer.
Then, add one side as inlet.
Give the conditions of Laminar Inflow in Boundary Condition with the given values.
Boundary Selection
Selection: Manual
Boundary Condition
Boundary condition:
Laminar inflow
Laminar Inflow
Average velocity
Flow rate
Entrance pressure
Average velocity:
0.0015
m/s
Entrance length:
0
m

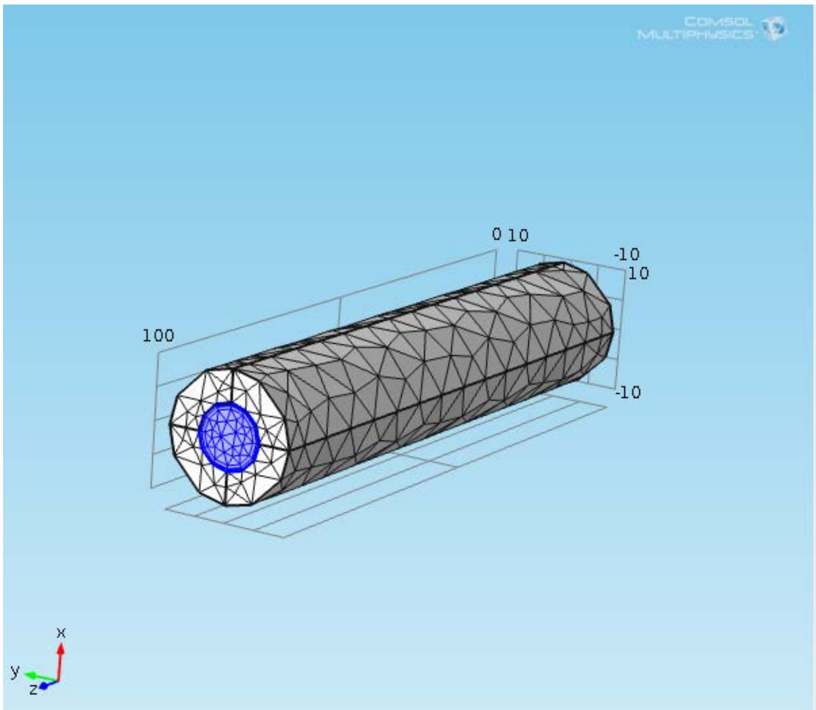

Similarly, add Outlet to the other side of inlet.
Selection: Manual
Boundary Condition
Boundary condition:
Laminar outflow
Average velocity
Flow rate
Exit pressure
Average velocity:
0.0015
m/s
Exit length:
0.1
m
Constrain outer edges to zero

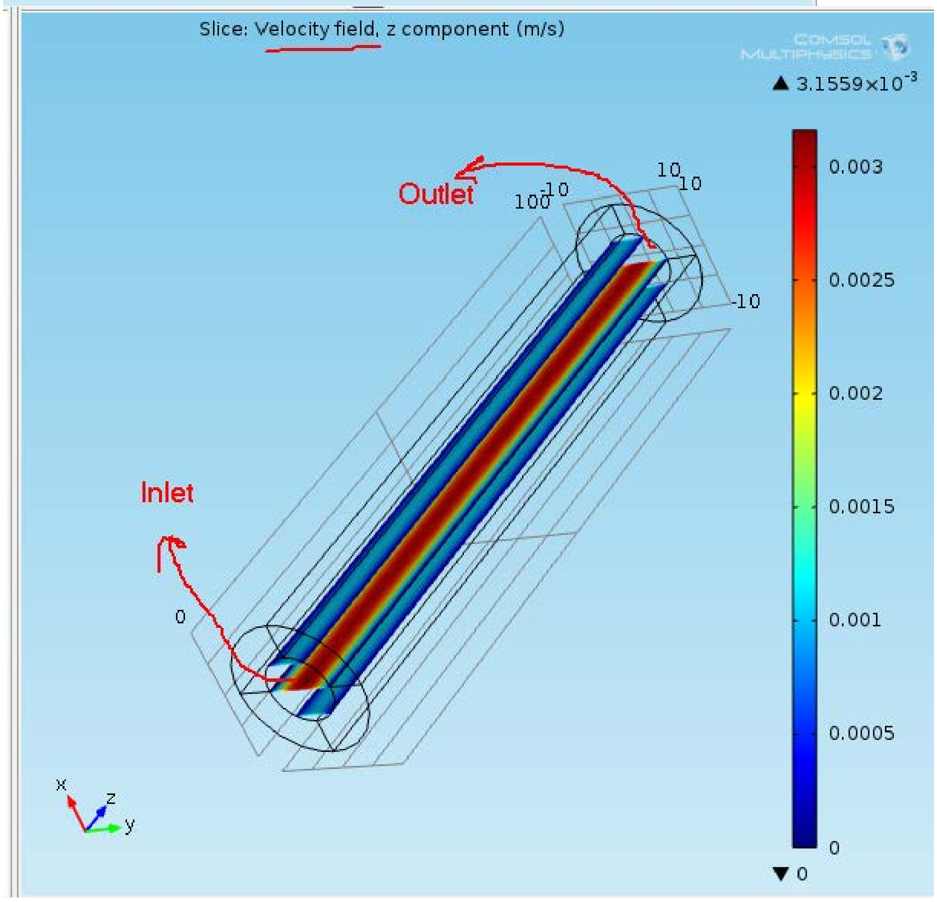

Remove the outer part (Poly-Si) because fluid is only moving inside.
Identifier: spf
Domain Selection
Selection: Manual
Physical Model
Compressibility:
Compressible flow (Ma<0.3)
Turbulence model type:
None
Neglect inertial term (Stokes flow)
Dependent Variables



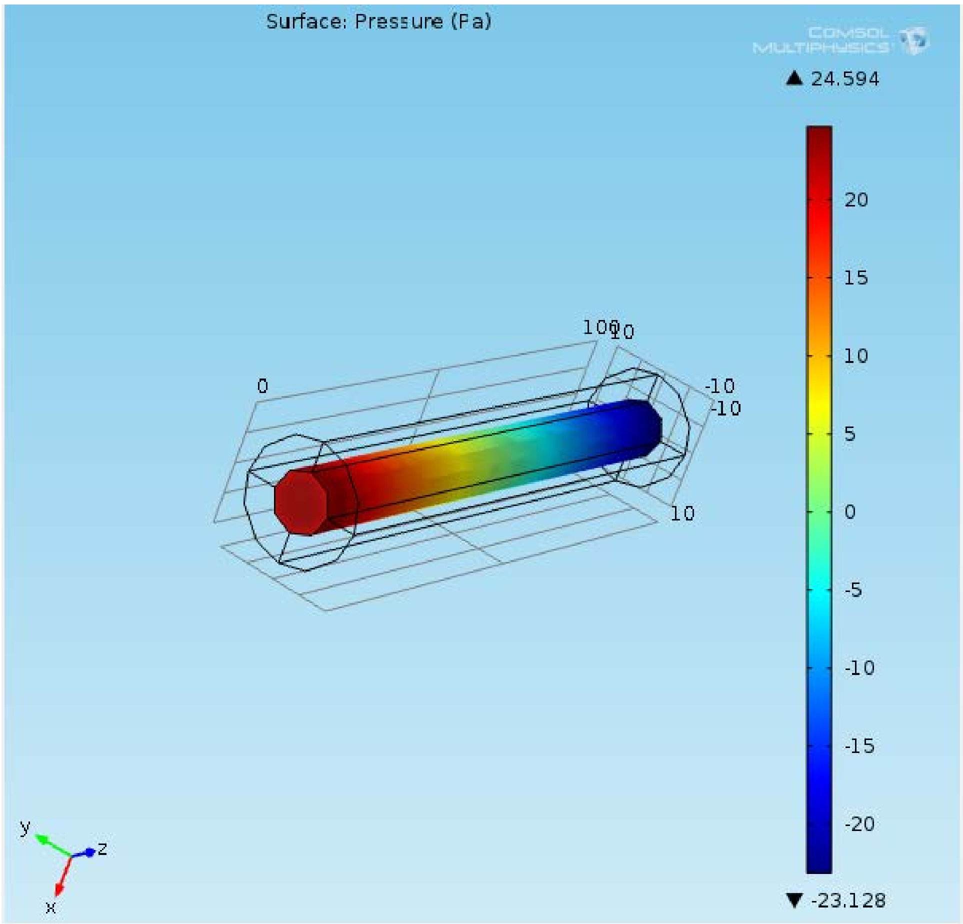
Note: In case you get the error saying, "Error: Maximum number of Newtonian Iterations reached" change the mesh amount from NORMAL TO EXTREMEMLY COARSE.



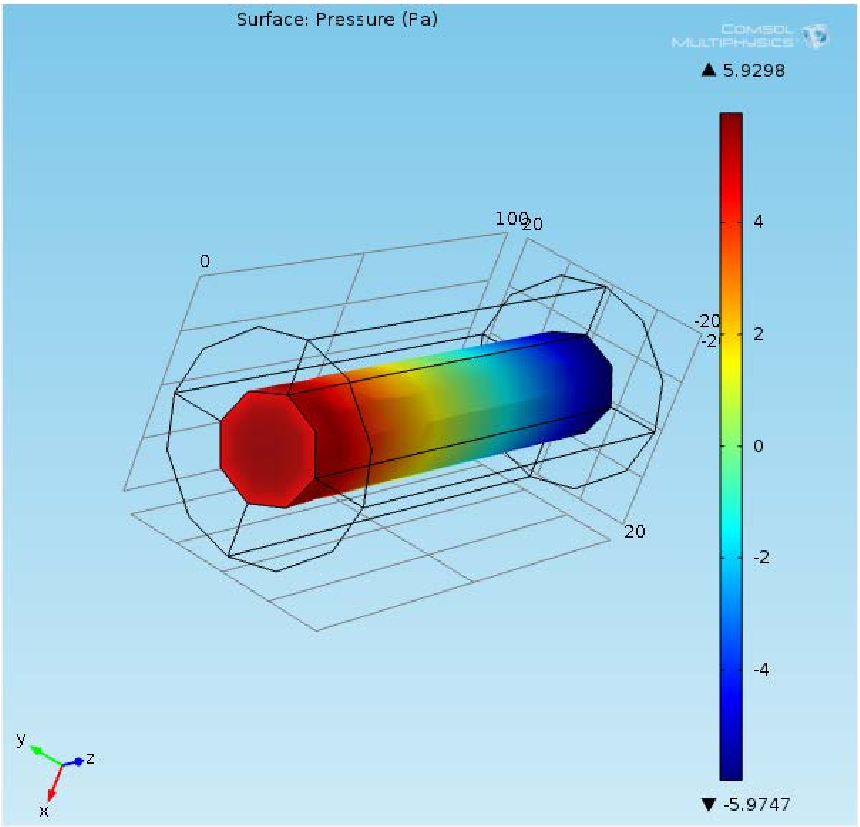


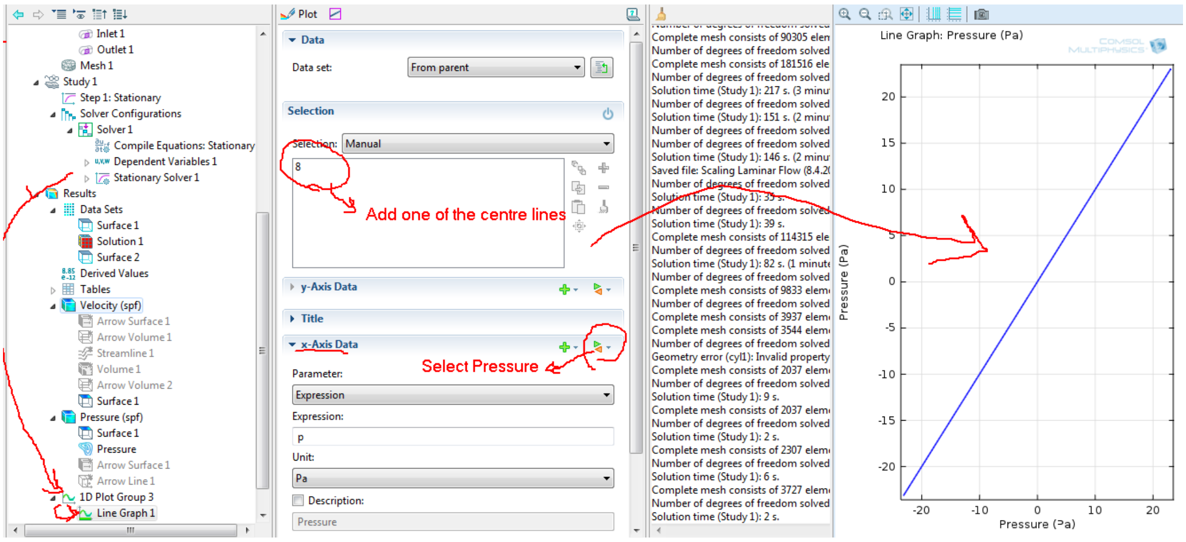


Radius is 5um



On changing the dimensions to 10um and 20um, we have this pressure.
(it decreases, as expected)
Radius is doubled (10um now)
So, by formula, Pressure is inversely proportional to the square of radius.
So, as radius is doubled, pressure is becoming 1/4 times.

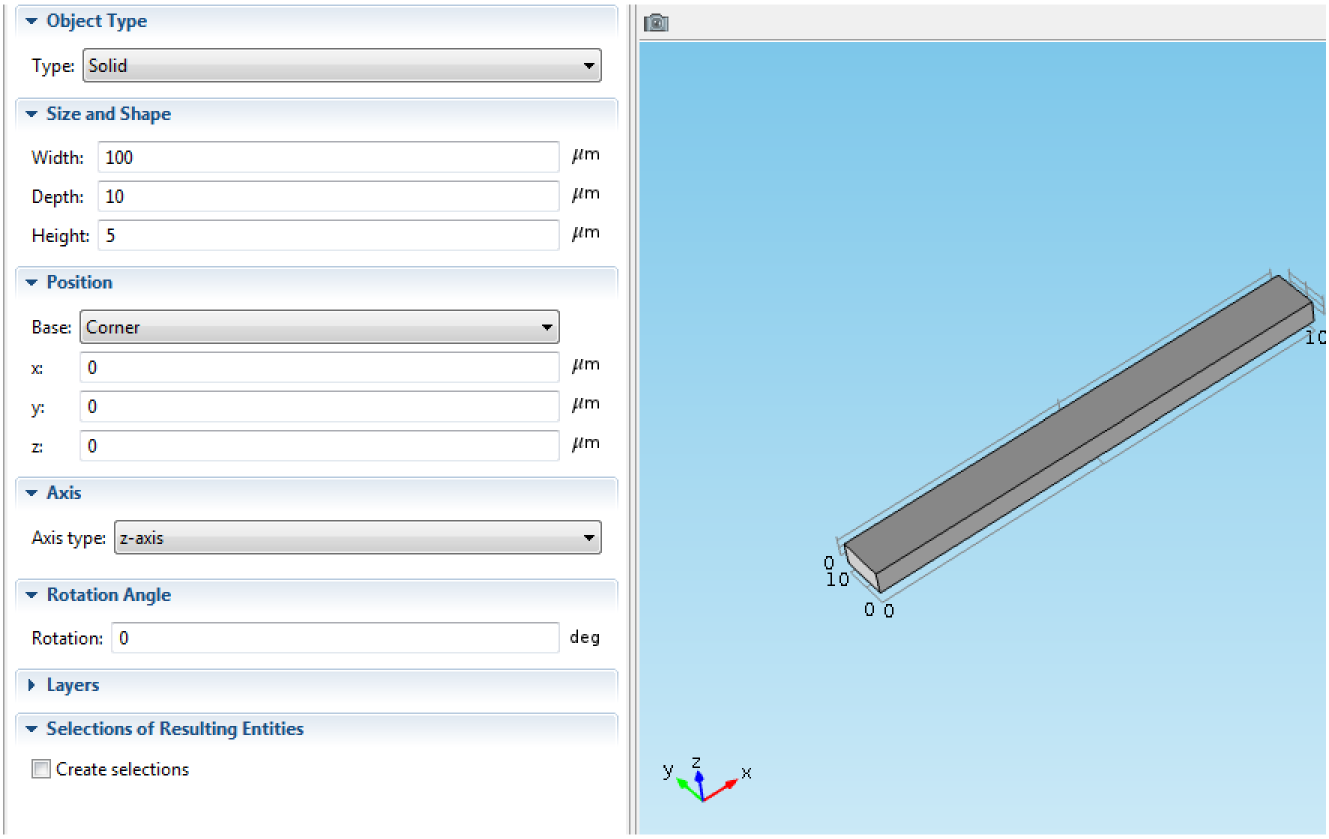

Surface: Pressure (Pa)
▲ 5.9298
▼ -5.9747

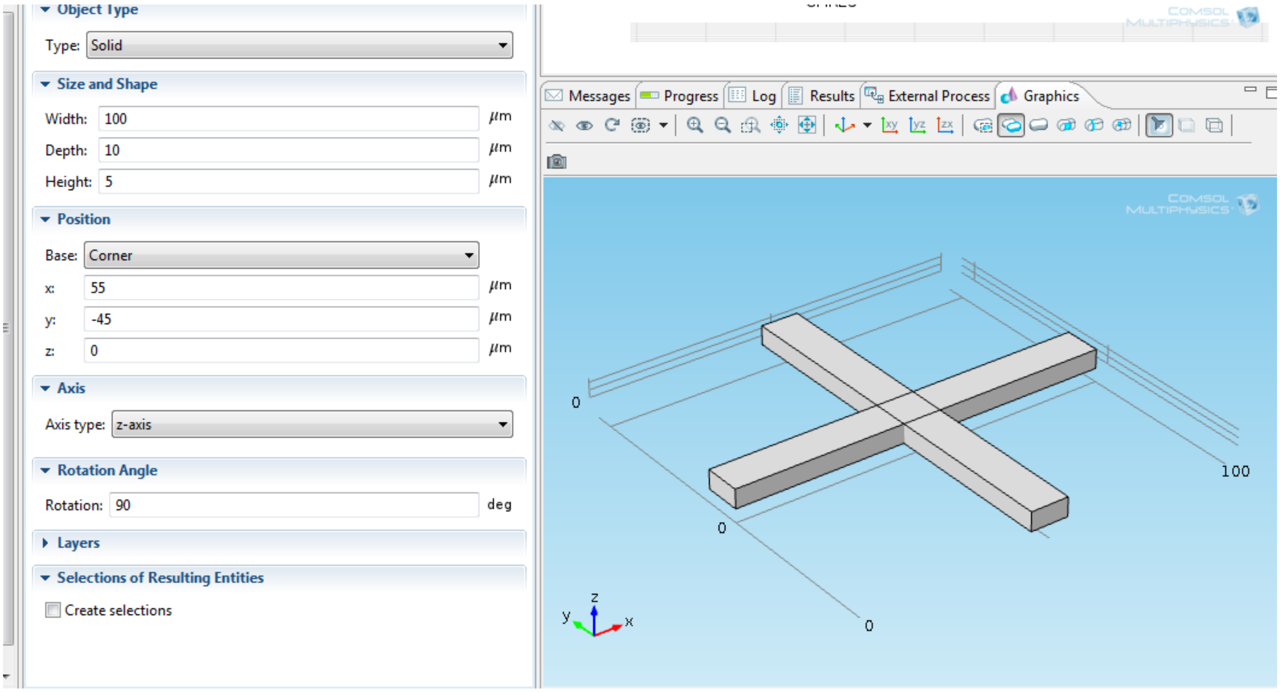

Add one of the centre lines
Select Pressure
Line Graph: Pressure (Pa)
Pressure (Pa)

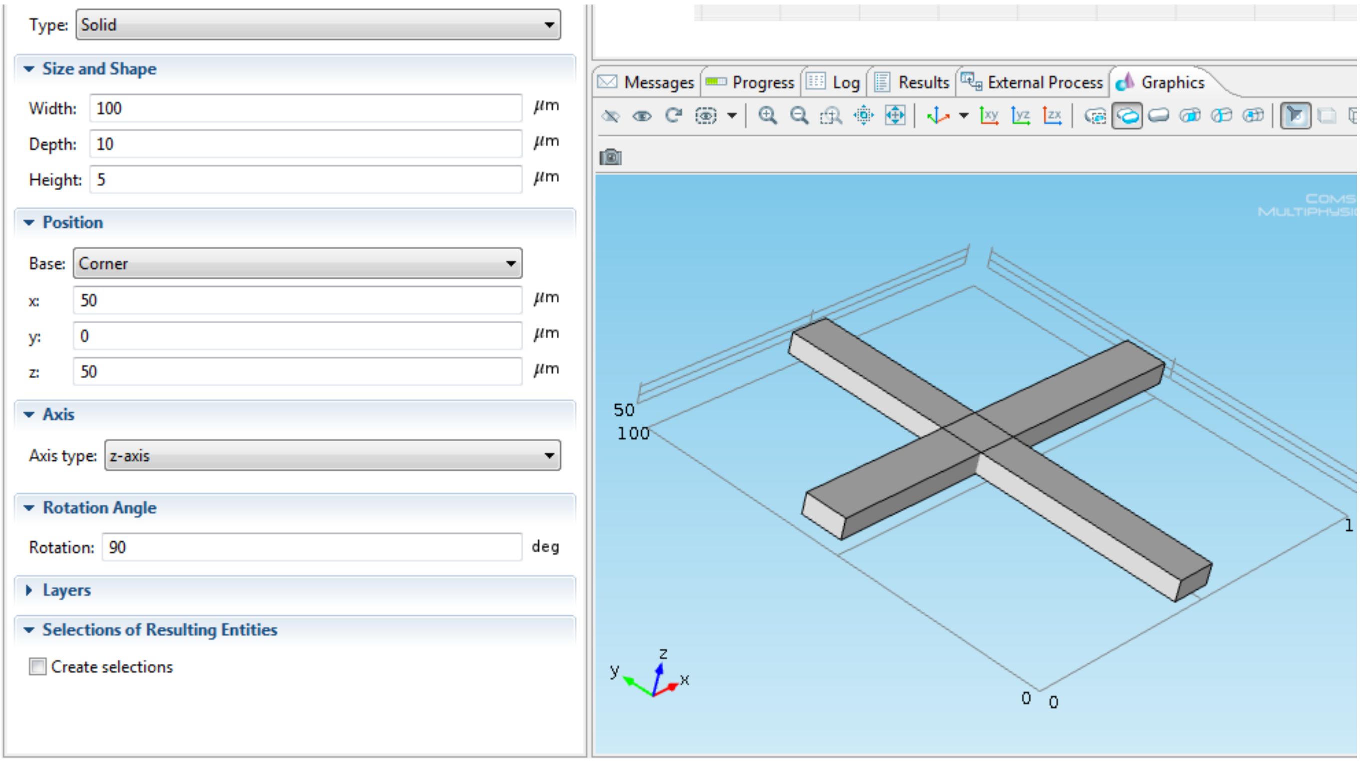
MICRO MIXER

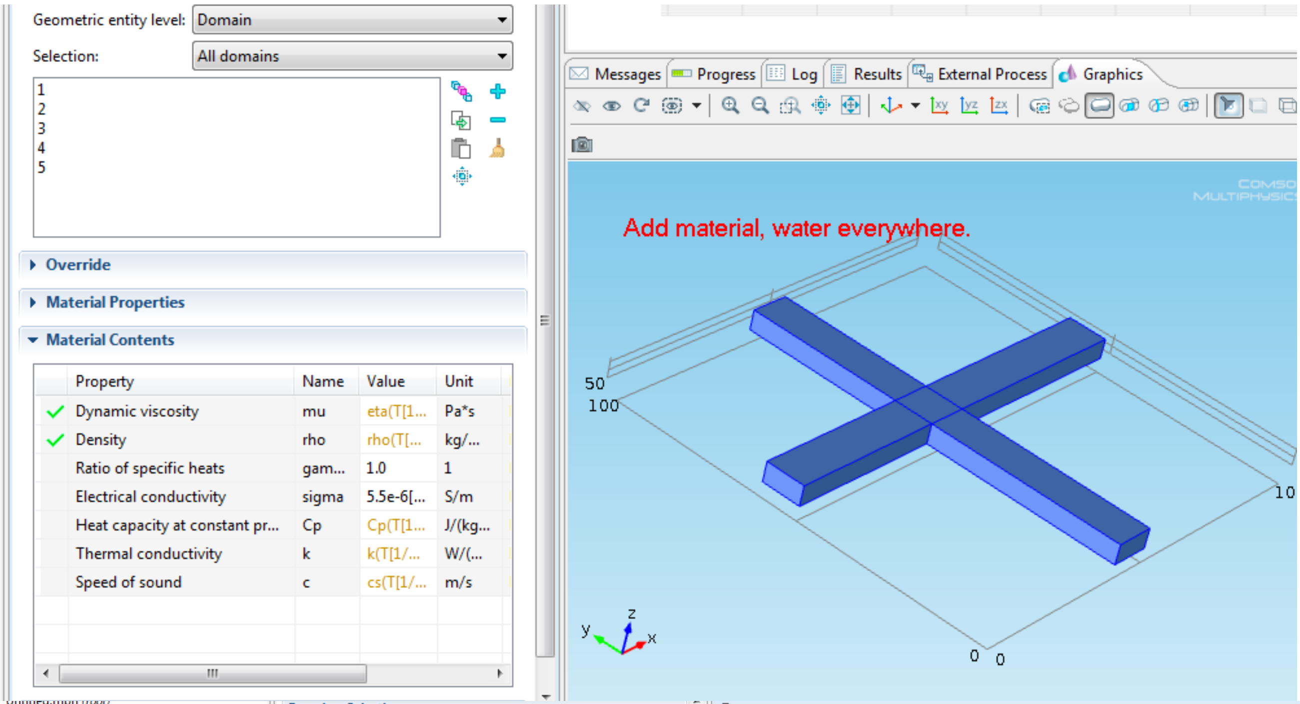
Model - 3D
Physics - Laminar Flow
Property - Stationary

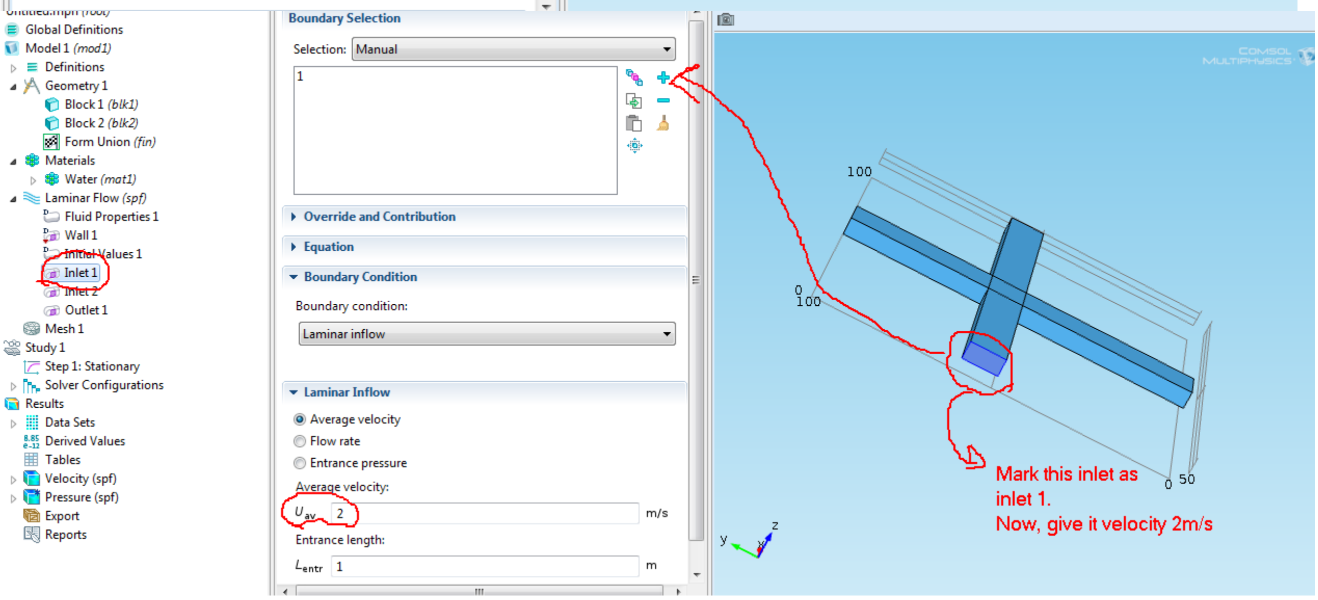
Make the model.

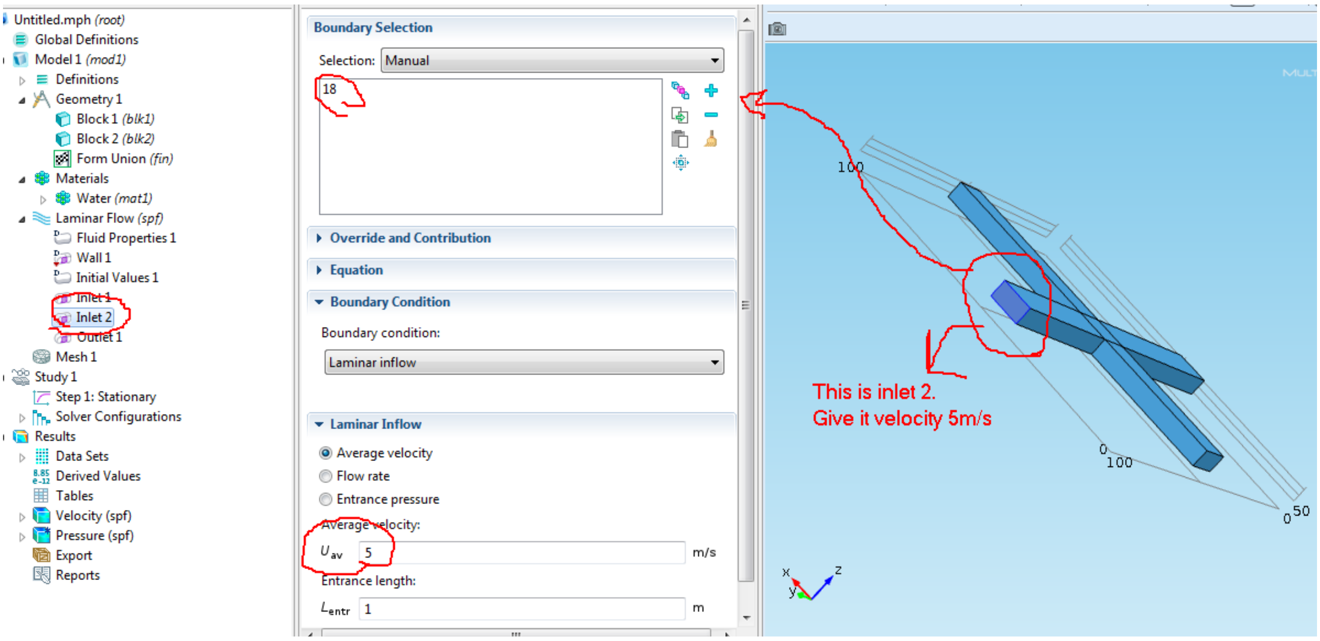


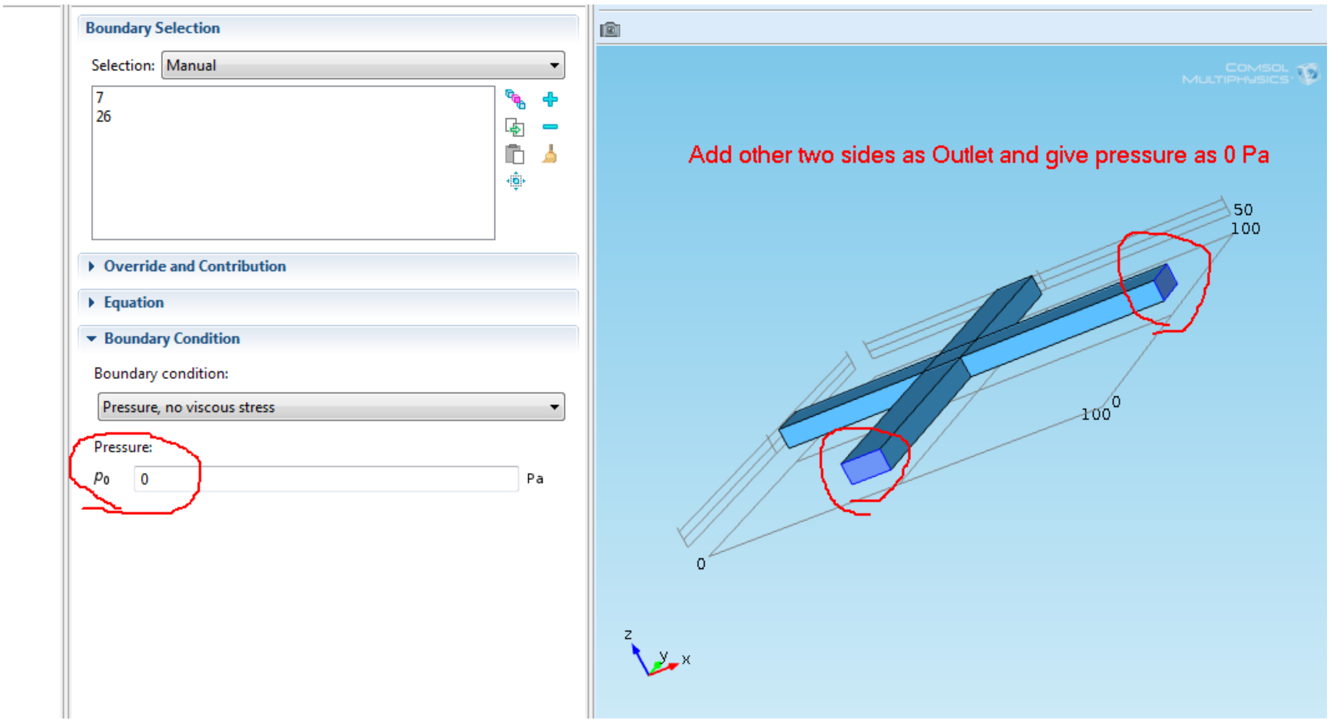

Object Type
Type: Solid
Size and Shape
Width: 100 µm
Depth: 10 µm
Height: 5 µm
Position
Base: Corner
x: 55 µm
y: -45 µm
z: 0 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 90 deg
Layers
Selections of Resulting Entities
Create selections
Messages
Progress
Log
Results
External Process
Graphics

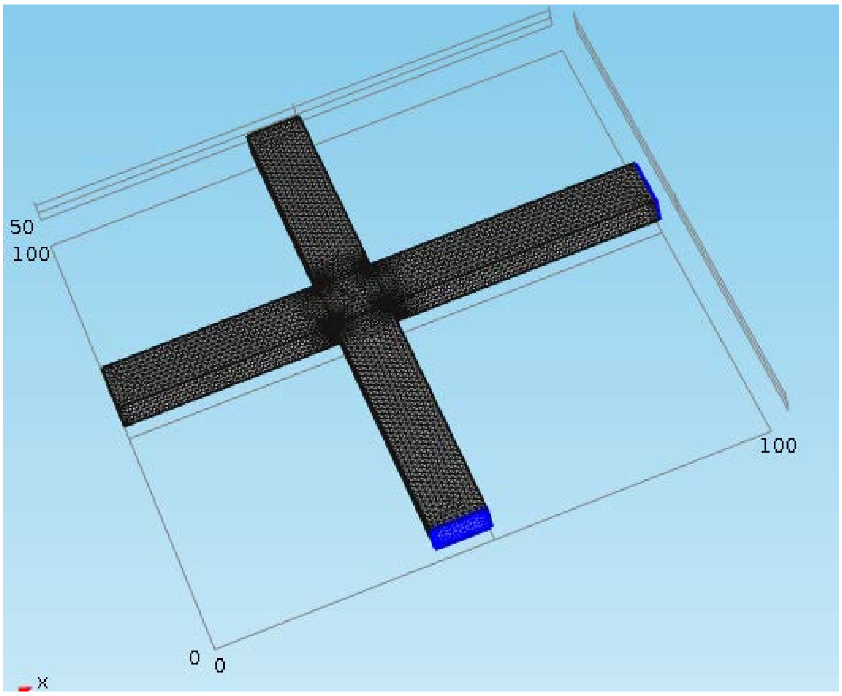

Type: Solid
Size and Shape
Width: 100 µm
Depth: 10 µm
Height: 5 µm
Position
Base: Corner
x: 50 µm
y: 0 µm
z: 50 µm
Axis
Axis type: z-axis
Rotation Angle
Rotation: 90 deg
Layers
Selections of Resulting Entities
Create selections
Messages
Progress
Log
Results
External Process
Graphics

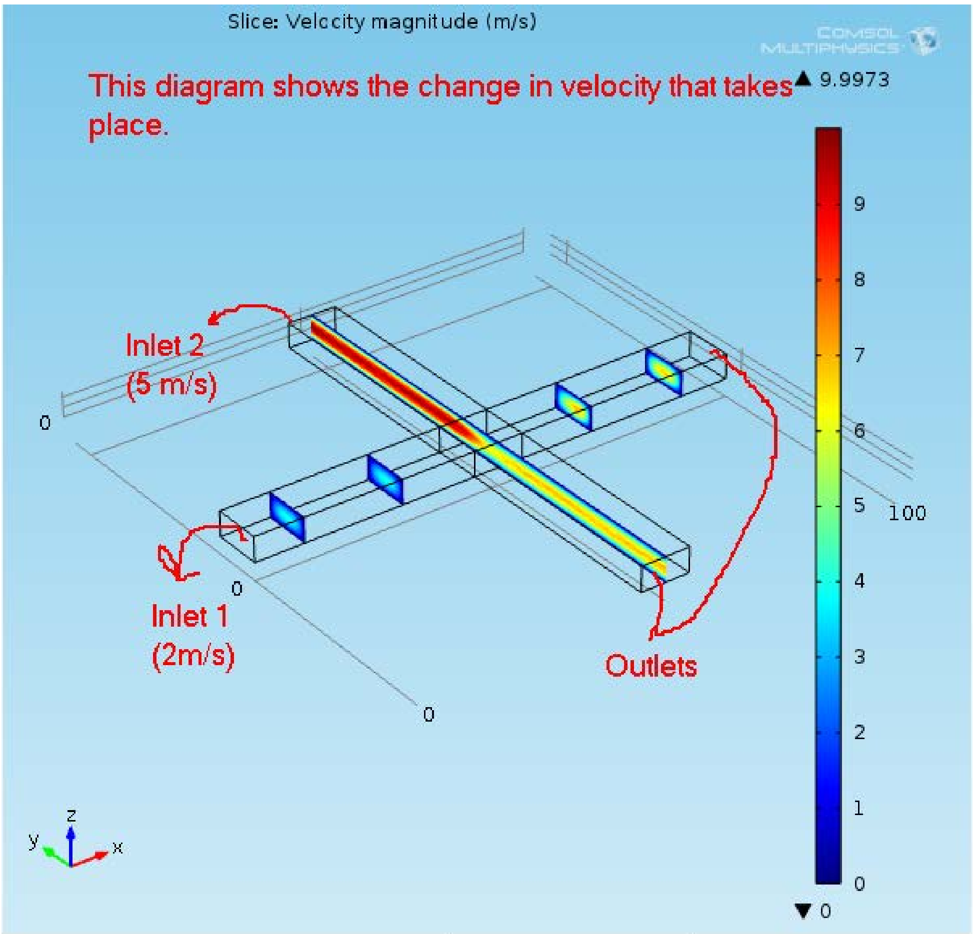

Geometric entity level: Domain
Selection: All domains
Override
Material Properties
Material Contents
Property Name Value Unit
Dynamic viscosity mu eta(T[1... Pa*s
Density rho rho(T[... kg/...
Ratio of specific heats gam... 1.0 1
Electrical conductivity sigma 5.5e-6[... S/m
Heat capacity at constant pr... Cp Cp(T[1... J/(kg...
Thermal conductivity k k(T[1/... W/(...
Speed of sound c cs(T[1/... m/s
Messages Progress Log Results External Process Graphics
Add material, water everywhere.

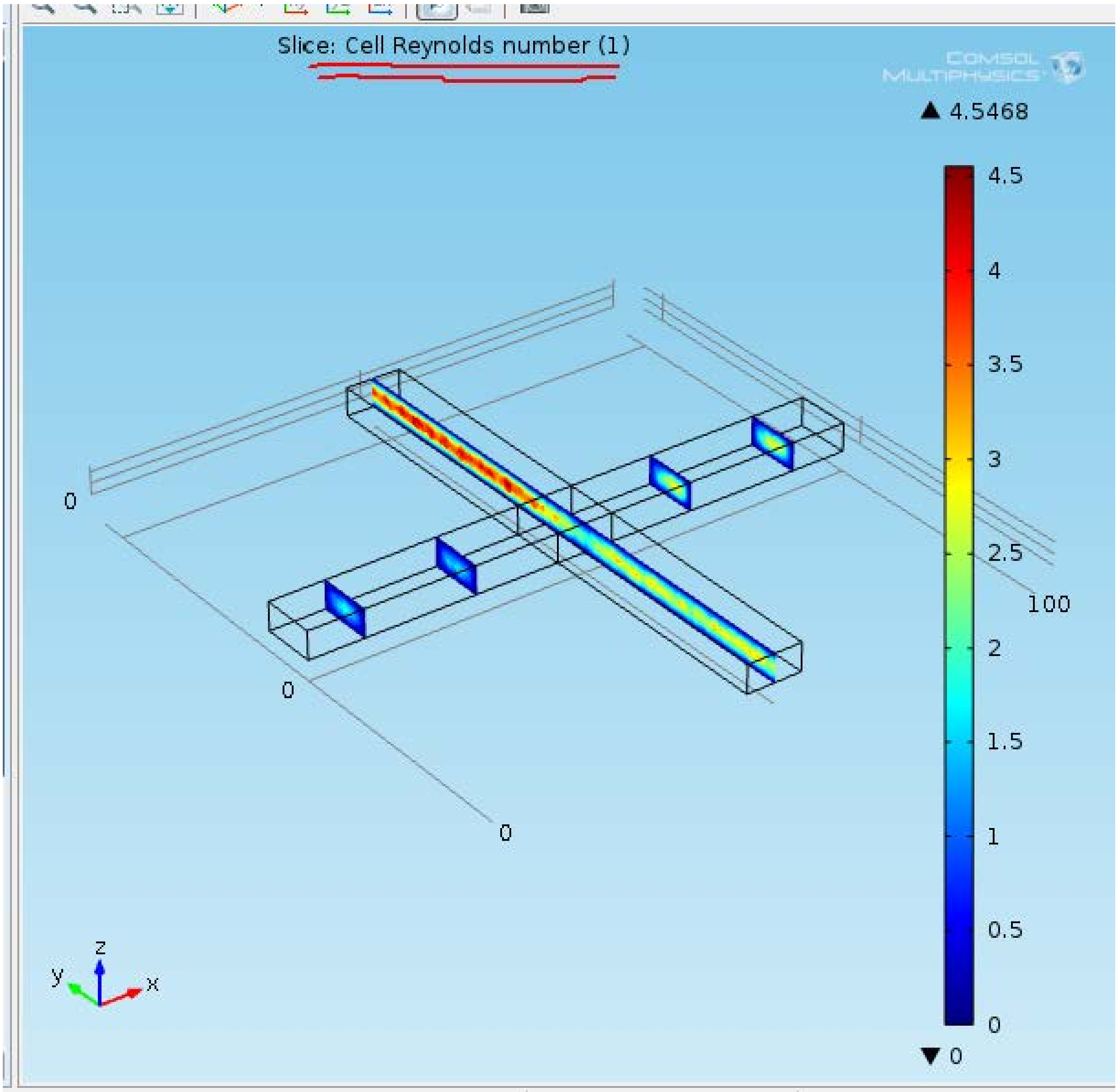

Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Block 2 (blk2)
Form Union (fin)
Materials
Water (mat1)
Laminar Flow (spf)
Fluid Properties 1
Wall 1
Initial Values 1
Inlet 1
Inlet 2
Outlet 1
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Results
Data Sets
Derived Values
Tables
Velocity (spf)
Pressure (spf)
Export
Reports
Boundary Selection
Selection: Manual
Override and Contribution
Equation
Boundary Condition
Boundary condition:
Laminar inflow
Laminar Inflow
Average velocity
Flow rate
Entrance pressure
Average velocity:
U_av 2 m/s
Entrance length:
L_entr 1 m
Mark this inlet as
inlet 1.
Now, give it velocity 2m/s


Untitled.mph (root)
Global Definitions
Model 1 (mod1)
Definitions
Geometry 1
Block 1 (blk1)
Block 2 (blk2)
Form Union (fin)
Materials
Water (mat1)
Laminar Flow (spf)
Fluid Properties 1
Wall 1
Initial Values 1
Inlet 1
Inlet 2
Outlet 1
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Results
Data Sets
Derived Values
Tables
Velocity (spf)
Pressure (spf)
Export
Reports
Boundary Selection
Selection: Manual
18
Override and Contribution
Equation
Boundary Condition
Boundary condition:
Laminar inflow
Laminar Inflow
Average velocity
Flow rate
Entrance pressure
Average velocity:
U av 5 m/s
Entrance length:
L entr 1 m
This is inlet 2.
Give it velocity 5m/s


Boundary Selection
Selection: Manual
7
26
Override and Contribution
Equation
Boundary Condition
Boundary condition:
Pressure, no viscous stress
Pressure:
p0 0 Pa
Add other two sides as Outlet and give pressure as 0 Pa

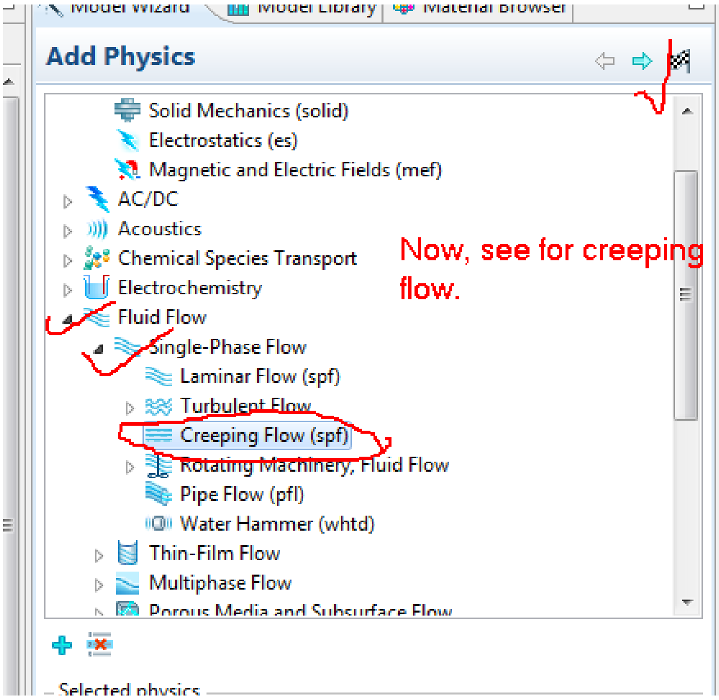

50
100
100
0
0
x

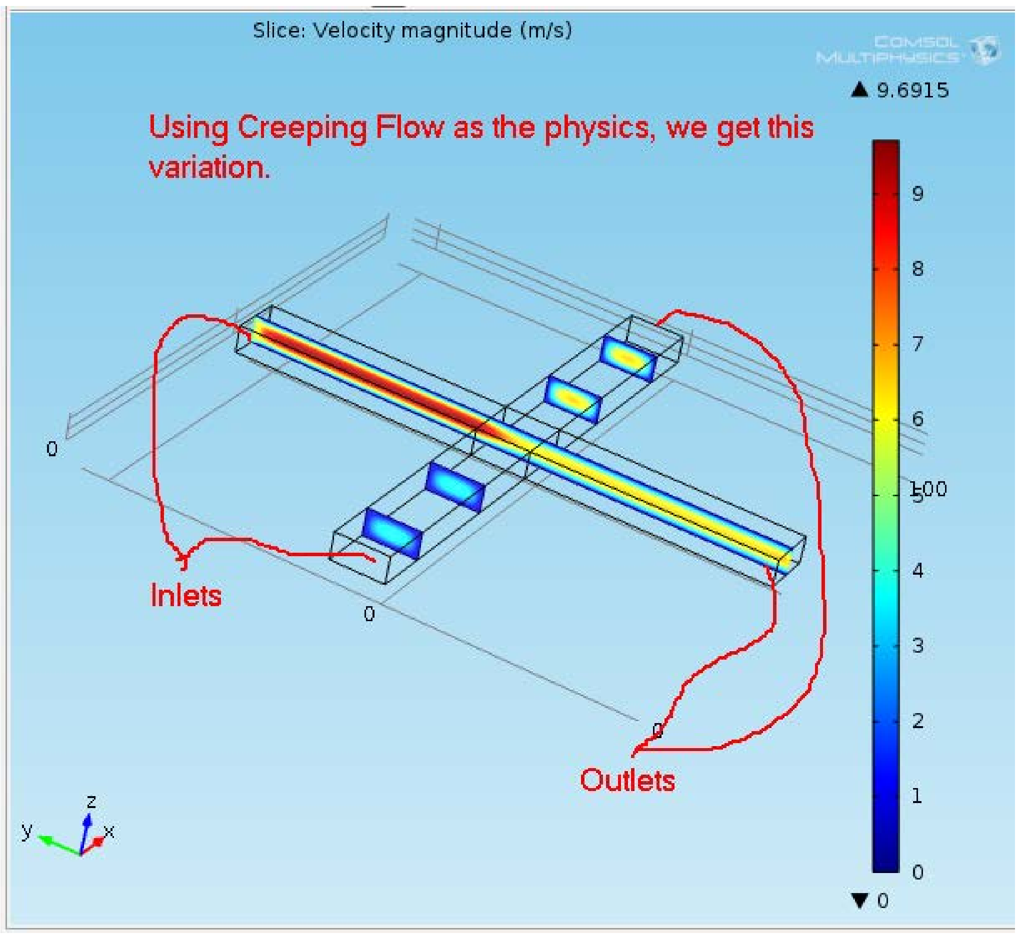

Slice: Velocity magnitude (m/s)
This diagram shows the change in velocity that takes place.
▲ 9.9973
Inlet 2
(5 m/s)
Inlet 1
(2m/s)
Outlets
9
8
7
6
5
4
3
2
1
0
▼ 0
100
0
0
0
y
z
x

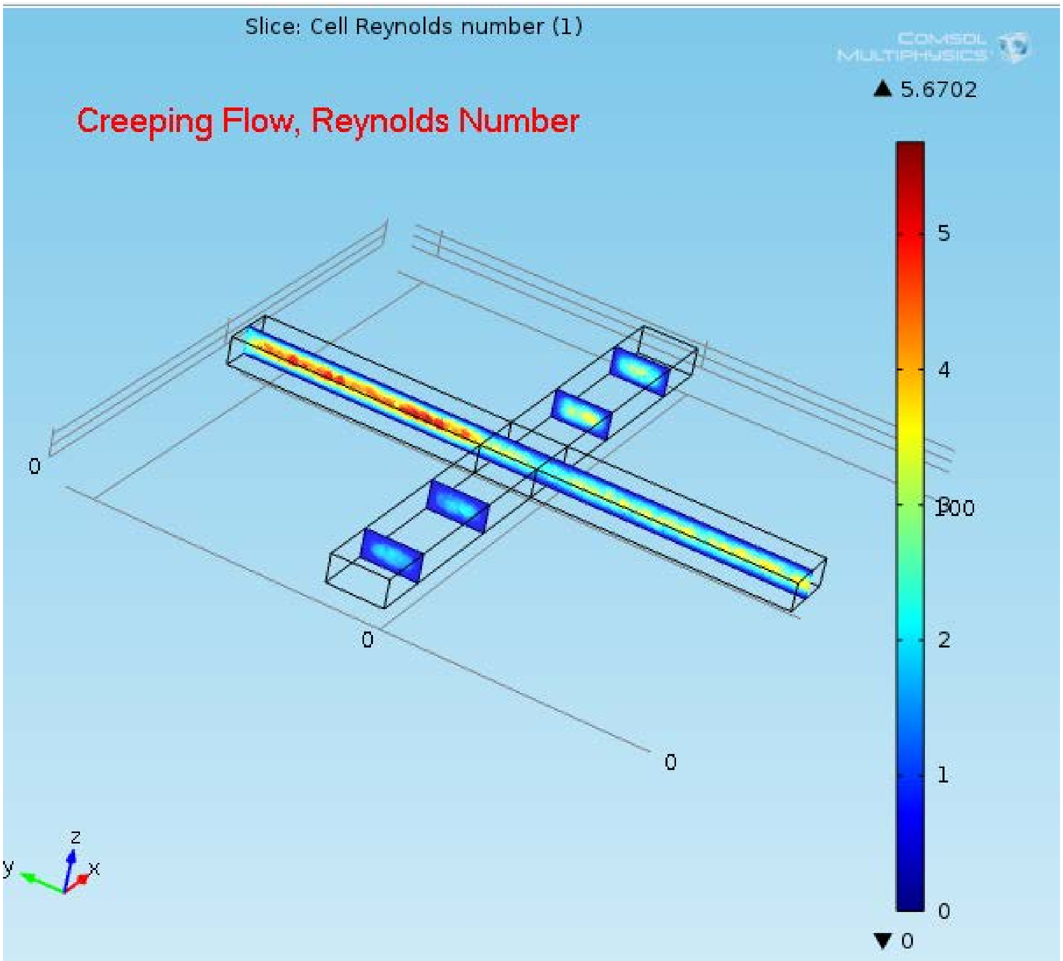


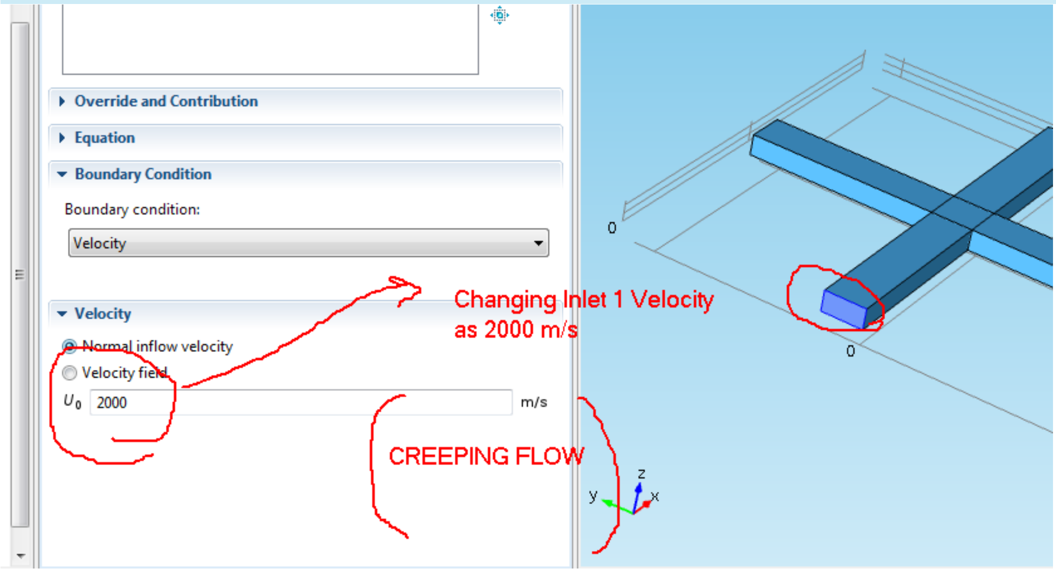
Slice: Cell Reynolds number (1)
▲ 4.5468
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
▼ 0
0
0
0
100
z
y
x

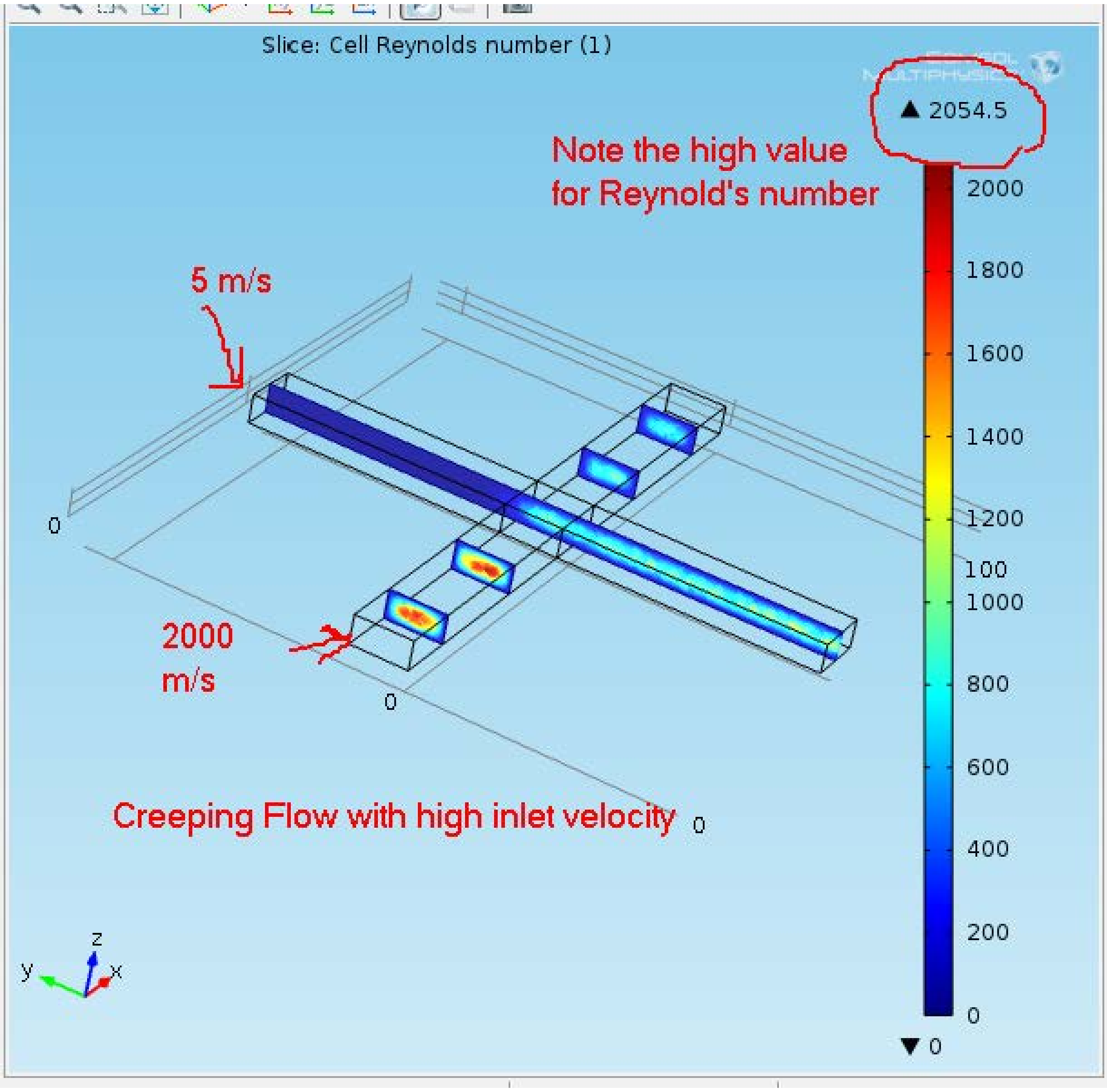
ONLY CREEPING FLOW



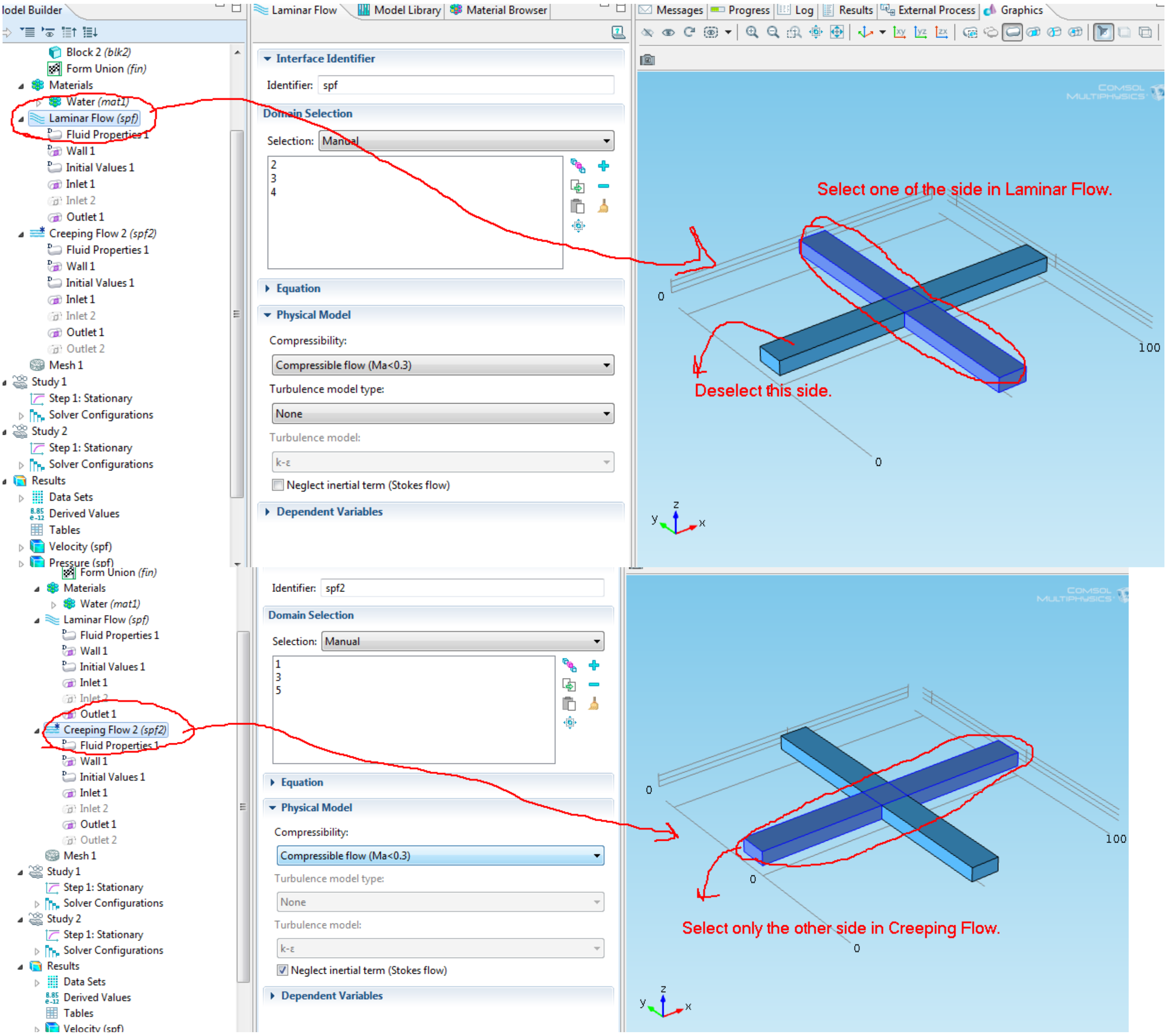


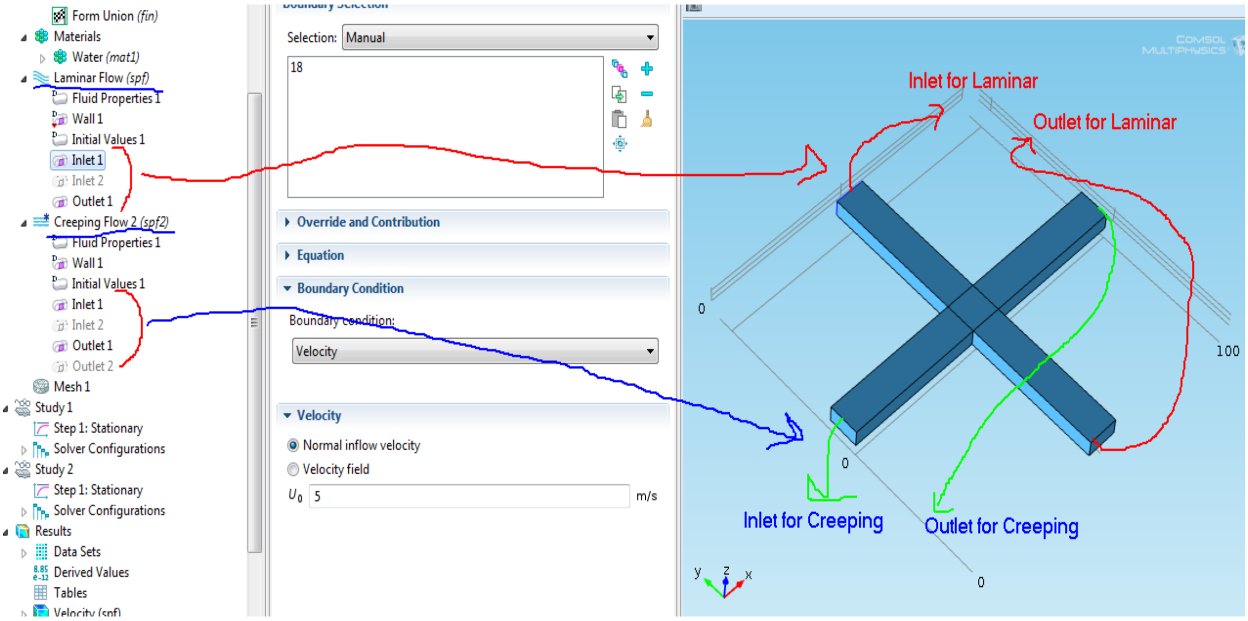

Slice: Cell Reynolds number (1)
COMSOL MULTIPHYSICS
▲ 5.6702
Creeping Flow, Reynolds Number
5
4
3
2
1
0
▼ 0
z
y
x


Override and Contribution
Equation
Boundary Condition
Boundary condition:
Velocity
Velocity
Normal inflow velocity
Velocity field
U_0 2000 m/s
Changing Inlet 1 Velocity
as 2000 m/s
CREEPING FLOW

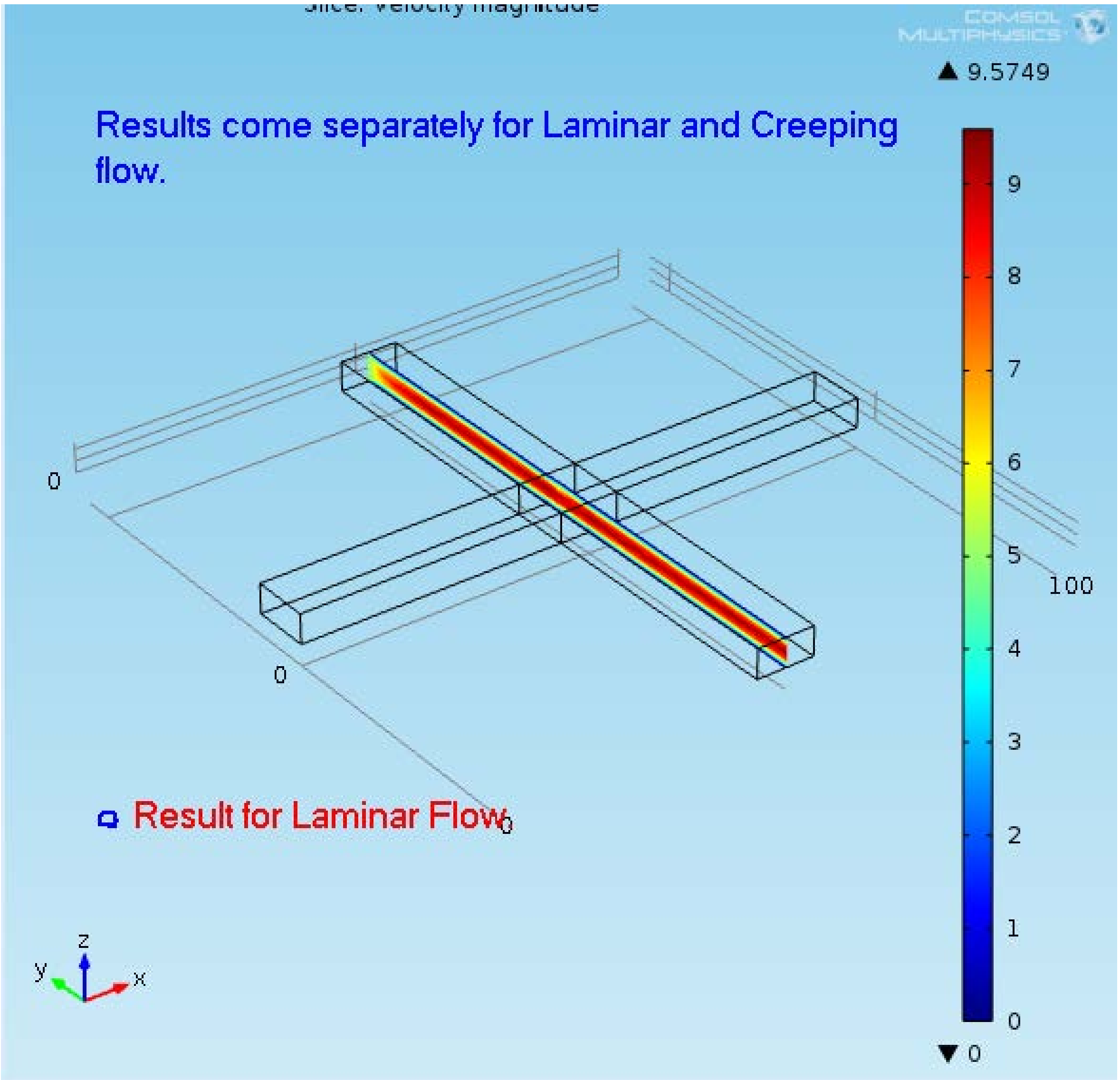

Slice: Cell Reynolds number (1)
▲ 2054.5
Note the high value
for Reynold's number
5 m/s
2000
m/s
Creeping Flow with high inlet velocity
2000
1800
1600
1400
1200
100
1000
800
600
400
200
0
▼ 0
z
y
x

ONE FLOW LAMINAR, ONE FLOW CREEPING

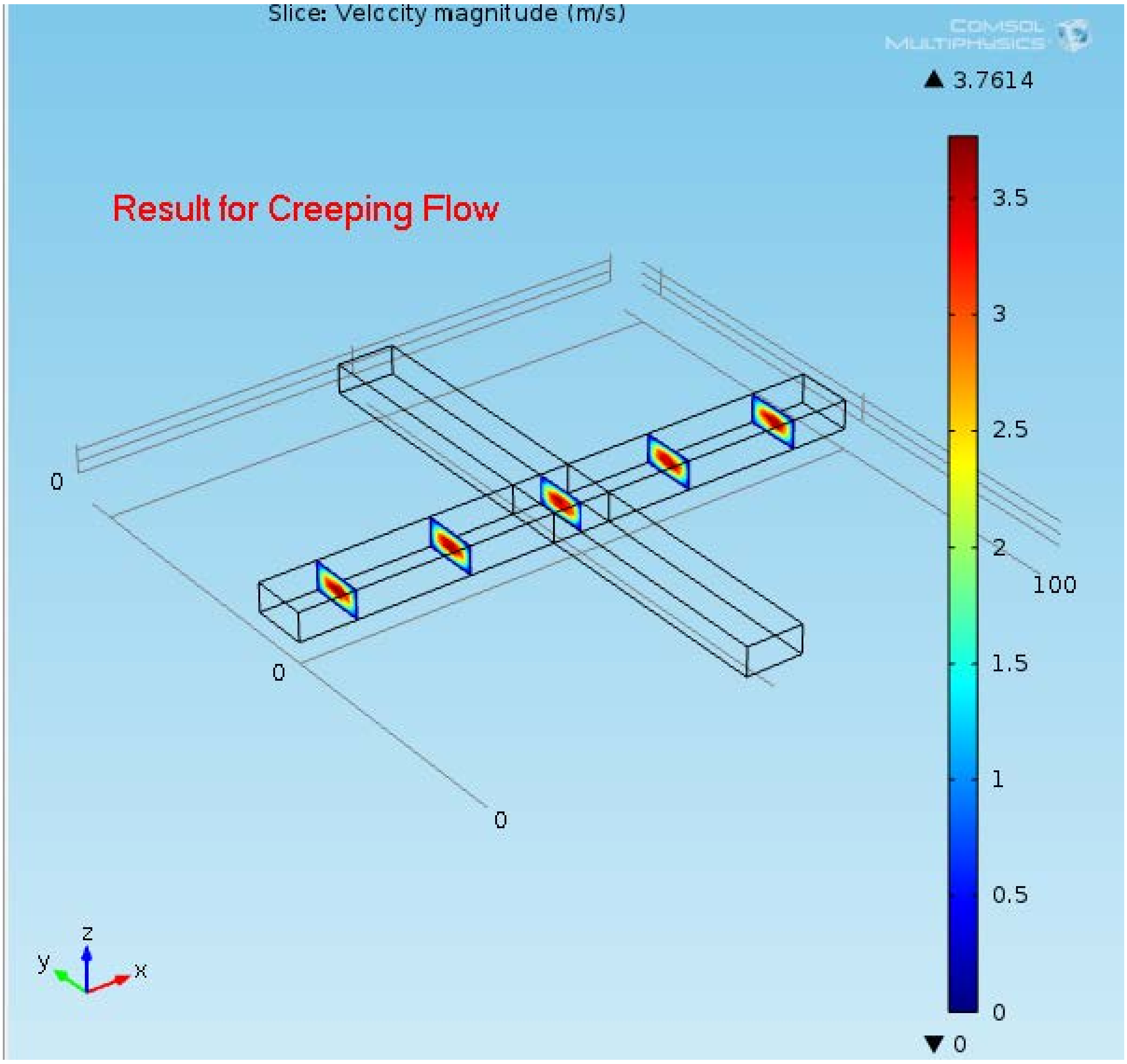




Form Union (fin)
Materials
Water (mat1)
Laminar Flow (spf)
Fluid Properties 1
Wall 1
Initial Values 1
Inlet 1
Inlet 2
Outlet 1
Creeping Flow 2 (spf2)
Fluid Properties 1
Wall 1
Initial Values 1
Inlet 1
Inlet 2
Outlet 1
Outlet 2
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Study 2
Step 1: Stationary
Solver Configurations
Results
Data Sets
Derived Values
Tables
Selection: Manual
18
Override and Contribution
Equation
Boundary Condition
Boundary condition:
Velocity
Velocity
Normal inflow velocity
Velocity field
U_0 5 m/s
Inlet for Laminar
Outlet for Laminar
Inlet for Creeping
Outlet for Creeping



9.5749
Results come separately for Laminar and Creeping flow.
Result for Laminar Flow


Slice: Velocity magnitude (m/s)
COMSOL MULTIPHYSICS
▲ 3.7614
Result for Creeping Flow
3.5
3
2.5
2
1.5
1
0.5
0
▼ 0
0
0
0
100
z
y
x

USING TWO FLUIDS, WATER AND ETHANOL