Continuation of Flows Between Parallel Plates & single plates
Modified from the COMSOL ChE Library module.

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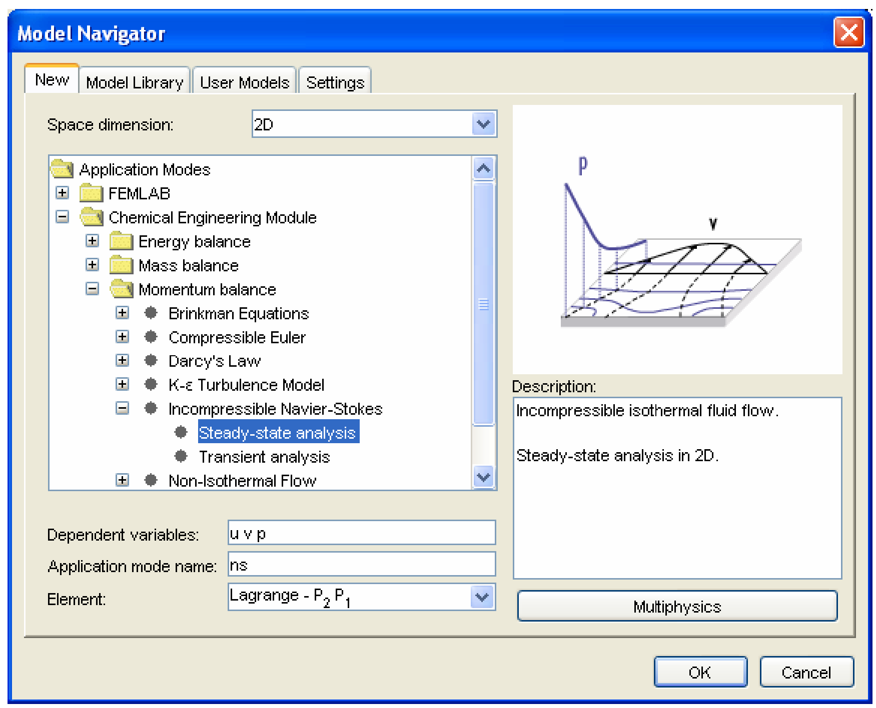
Laminar Flow Between Horizontal Plates with One Plate Moving
Derive the unsteady-state momentum balance for a Newtonian fluid flowing between two plates in which the motion of the fluid between the 2 plates is created by one plate moving at a velocity v0 and the second parallel plate stationary. Submit this derivation at the end of the class. Is the resulting equation linear or nonlinear? In the following COMSOL simulation make sure you set your solver to the appropriate solver type (See Solver Parameters). Find an analytical solution for the stress and velocity profile.

Now have one plate moving and have the initial velocity at the entrance set to zero. You don't have to change the geometry. Just exclude gravity from any of the model terms. (you already have done this in a previous lab). Use the fully developed boundary condition.
Plot: Cross section plot

Modeling using the Graphical User Interface

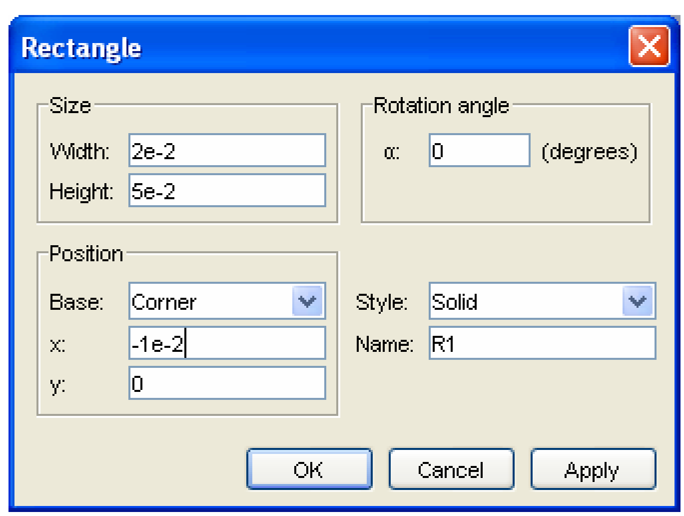
1. Start COMSOL
2. In the **Model Navigator** , click the **New** page
3. Select **Chemical Engineering Module**, **Momentum Balance**, **Incompressible Navier-Stokes**, Steady-state analsis
4. Click **OK.**



Options and Settings

Define the following constants in the **Constants** dialog box in the **Option** menu. Note this is not water and eta is COMSOL's notation for viscosity.

NAME	EXPRESSION
rho	1e3
eta	1e-2
v0	2e-2

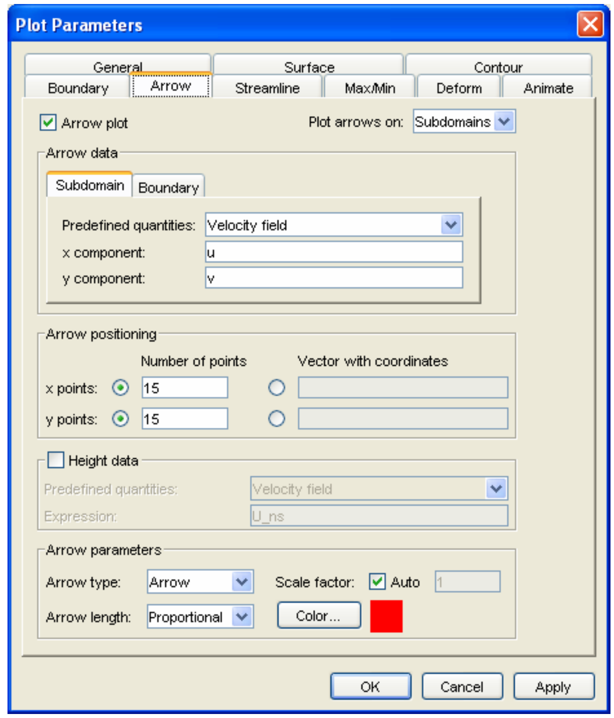


Geometry Modeling

1. Press the **Shift** key and click the **Rectangle/Square** button.
2. Type the values shown in the above figure for the rectangle dimensions.
3. Click the **Zoom Extents** button in the Main toolbar.

Now specify that the top plane is moving at a velocity v0 and the bottom plane is stationary.

Solve the model using the appropriate solver.



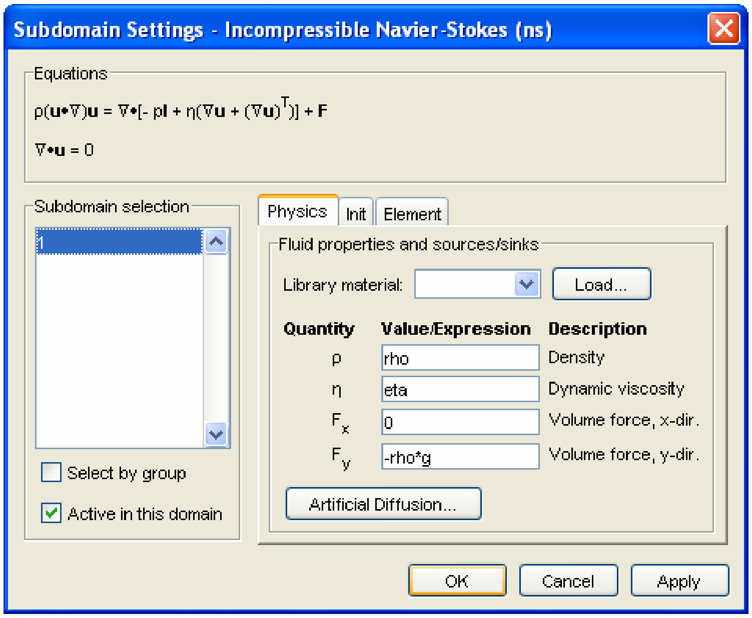
Make a contour plot showing (default solution) and add arrows to your plot showing the magnitude and direction of the velocity vectors. (Go to Plot Parameters and select the Arrow tab). Next make a cross-section plot of the velocity. Using excel compare the COMSOL and analytical results by plotting them on the same graph.

Laminar Flow – Vertical Falling film

Derive the unsteady-state momentum balance for a Newtonian fluid flowing down a single vertical plate. Submit this derivation at the end of the class. Is the resulting equation linear or nonlinear? Find an analytical solution for the stress and velocity profile.

Now solve a problem using a gravity term. In this case you will simulate a vertical plate with liquid flowing down the plate. Assume that the film thickness is 0.002m and the length of the plate is 0.01 m. Change your fluid physical properties to give a viscosity to 0.15 kg/(m s) and the thickness of the film to 0.002 m.

You have no applied pressure terms, but you will use a force term. The volume force vector, $\mathbf{F} = (F_x, F_y, F_z)$, describes a distributed force field such as gravity. The unit of the volume force is force/volume. In this model you will need a force per area term which operates in the negative y-direction. Enter this into the Subdomain Settings.



Add arrows to your contour plot showing the magnitude and direction of the velocity vectors.

Make a contour plot showing (default solution) and add arrows to your plot showing the magnitude and direction of the velocity vectors. (Go to Plot Parameters and select the Arrow tab). Next make a cross-section plot of the velocity. Using excel compare the COMSOL and analytical results by plotting them on the same graph.

Submit:

1. **Cross Section Plots:**
   1.1. Vertical Moving Plate
   1.2. Falling Film
2. Contour Plots (Basic Solution) Add arrows on top of plot to signify velocity
   2.1. Vertical Moving Plate
   2.2. Falling Film
3. Excel Plots comparing the fully developed flow analytical solution with
   3.1. the solution from a horizontal plate moving produced by COMSOL
   3.2. the solution from a falling film produced by COMSOL
4. All derivations