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Home final

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1. Global Definitions

|  |  |
| --- | --- |
| Date | Dec 1, 2021 5:36:01 AM |

Global settings

|  |  |
| --- | --- |
| Name | Home final.mph |
| Path | C:\Users\Shika\Desktop\Courses\3-1\Project\Comsol\home\_final.mph |
| Version | COMSOL Multiphysics 5.6 (Build: 280) |
| Unit system | SI |

Used products

|  |
| --- |
| COMSOL Multiphysics |
| CAD Import Module |
| LiveLink™ for PTC® Creo® Parametric™ |
| Microfluidics Module |

Computer information

|  |  |
| --- | --- |
| CPU | Intel64 Family 6 Model 142 Stepping 12, 4 cores |
| Operating system | Windows 10 |

* 1. Parameters

Parameters 1

| **Name** | **Expression** | **Value** | **Description** |
| --- | --- | --- | --- |
| uL | 1 [mm/s] | 0.001 m/s | Left Inlet Velocity |
| cL | 1 [mol/m^3] | 1 mol/m³ | Left Inlet Concentration |
| D | 1e-11 [m^2/s] | 1E−11 m²/s | Diffusion Constant |
| t | 0 [s] | 0 s | Start time |
| uR | 5 [mm/s] | 0.005 m/s | Right Inlet Velocity |
| cR | 10 [mol/m^3] | 10 mol/m³ | Right Inlet Concentration |

1. Component 1

|  |  |
| --- | --- |
| Date | Dec 1, 2021 1:05:58 AM |

Settings

| **Description** | **Value** |
| --- | --- |
| Unit system | Same as global system (SI) |
| Geometry shape function | Automatic |

Spatial frame coordinates

| **First** | **Second** | **Third** |
| --- | --- | --- |
| x | y | z |

Material frame coordinates

| **First** | **Second** | **Third** |
| --- | --- | --- |
| X | Y | Z |

Geometry frame coordinates

| **First** | **Second** | **Third** |
| --- | --- | --- |
| Xg | Yg | Zg |

Mesh frame coordinates

| **First** | **Second** | **Third** |
| --- | --- | --- |
| Xm | Ym | Zm |

* 1. Definitions
     1. Coordinate Systems

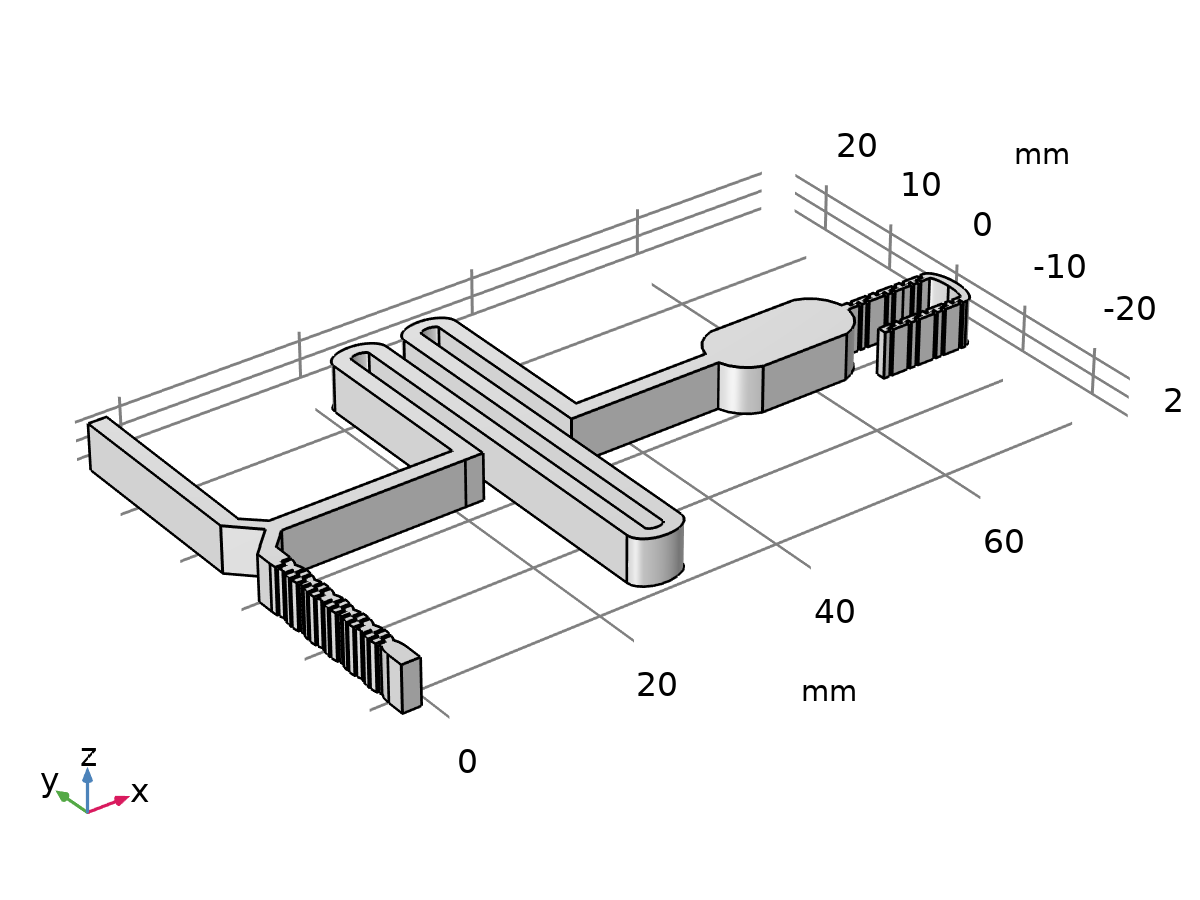
#### Boundary System 1

|  |  |
| --- | --- |
| Coordinate system type | Boundary system |
| Tag | sys1 |

Coordinate names

| **First** | **Second** | **Third** |
| --- | --- | --- |
| t1 | t2 | n |

* 1. Geometry 1



Geometry 1

Units

|  |  |
| --- | --- |
| Length unit | mm |
| Angular unit | deg |

Geometry statistics

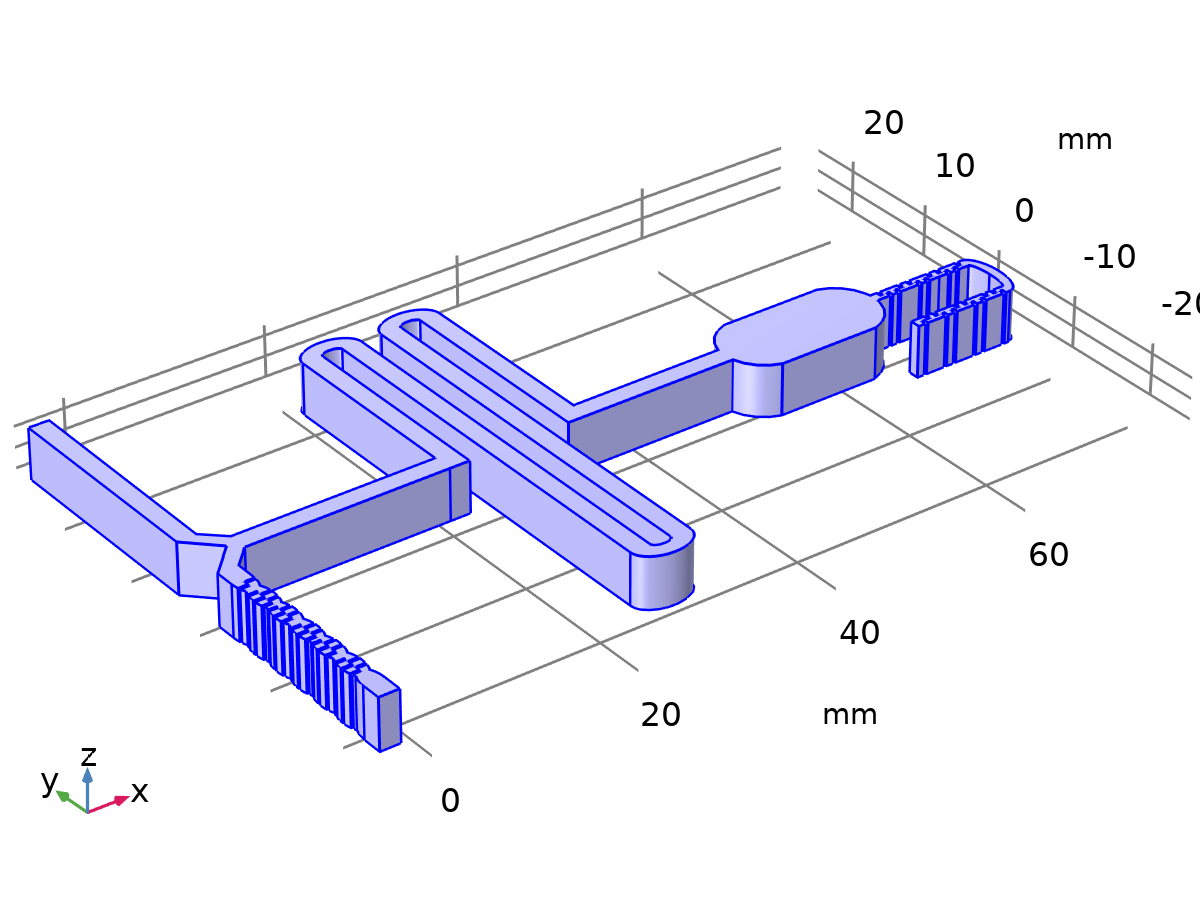
| **Description** | **Value** |
| --- | --- |
| Space dimension | 3 |
| Number of domains | 1 |
| Number of boundaries | 269 |
| Number of edges | 801 |
| Number of vertices | 534 |

* + 1. LiveLink for PTC Creo Parametric 1 (cad1)

Settings

| **Description** | **Value** |
| --- | --- |
| Synchronize with | Specified document |
| Document | C:\Users\Shika\Desktop\Courses\3 - 1\Project\Creo\HOME\_F.prt |
| Instance | GENERIC |
| Simplified representation | Master Rep |

* 1. Materials
     1. Material 1



Material 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1: Dimension 3: All domains |

Material parameters

| **Name** | **Value** | **Unit** |
| --- | --- | --- |
| Density | 1005 | kg/m³ |
| Dynamic viscosity | 0.00109 | Pa·s |

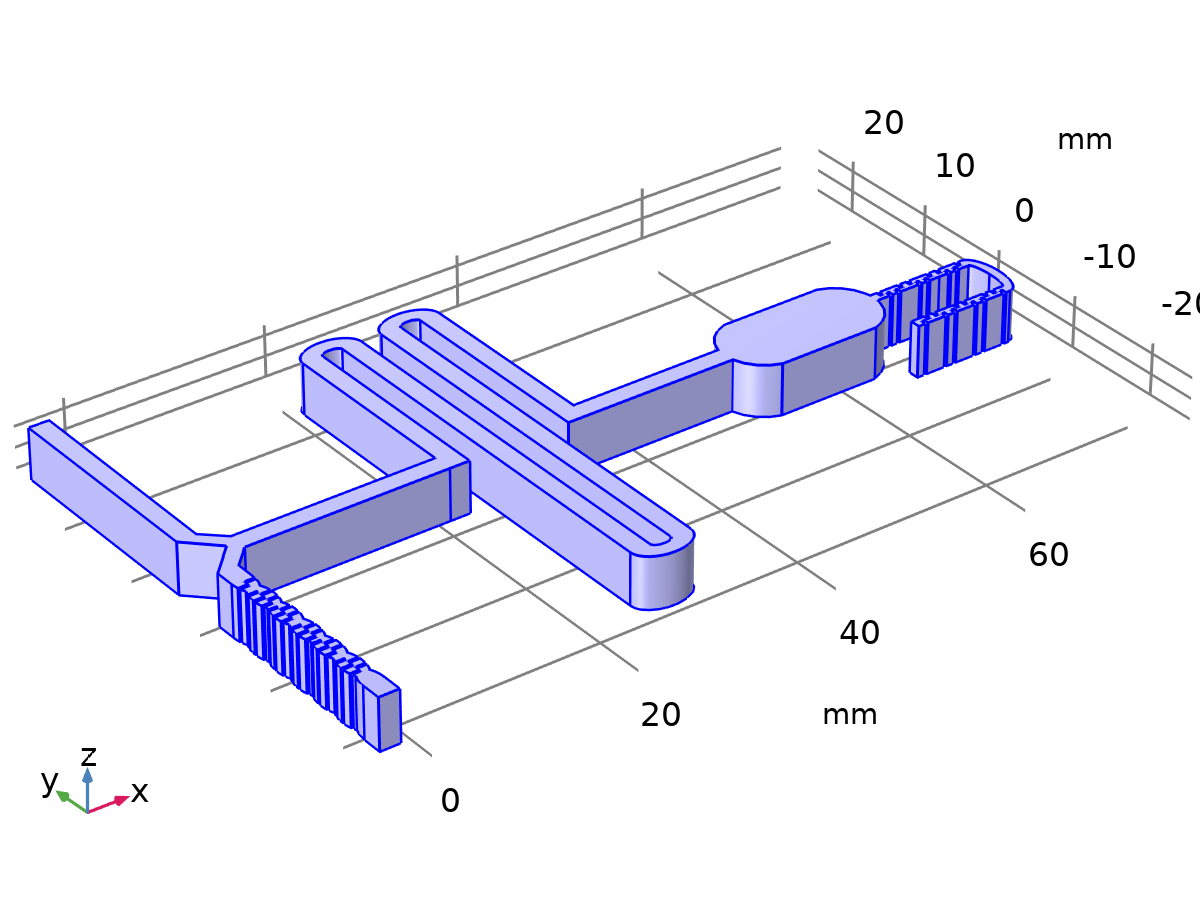
Basic

| **Description** | **Value** |
| --- | --- |
| Density | 1005 |
| density\_symmetry | 0 |
| Dynamic viscosity | 0.00109 |
| dynamicviscosity\_symmetry | 0 |

* 1. Laminar Flow

Used products

|  |
| --- |
| COMSOL Multiphysics |
| Microfluidics Module |



Laminar Flow

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1: Dimension 3: All domains |

Equations





* + 1. Interface Settings

#### Discretization

Settings

| **Description** | **Value** |
| --- | --- |
| Discretization of fluids | P2 + P1 |

#### Physical Model

Settings

| **Description** | **Value** |
| --- | --- |
| Neglect inertial term (Stokes flow) | Off |
| Compressibility | Incompressible flow |
| Enable porous media domains | Off |
| Include gravity | Off |
| Reference temperature | User defined |
| Reference temperature | 293.15[K] |
| Reference pressure level | 1[atm] |

#### Turbulence

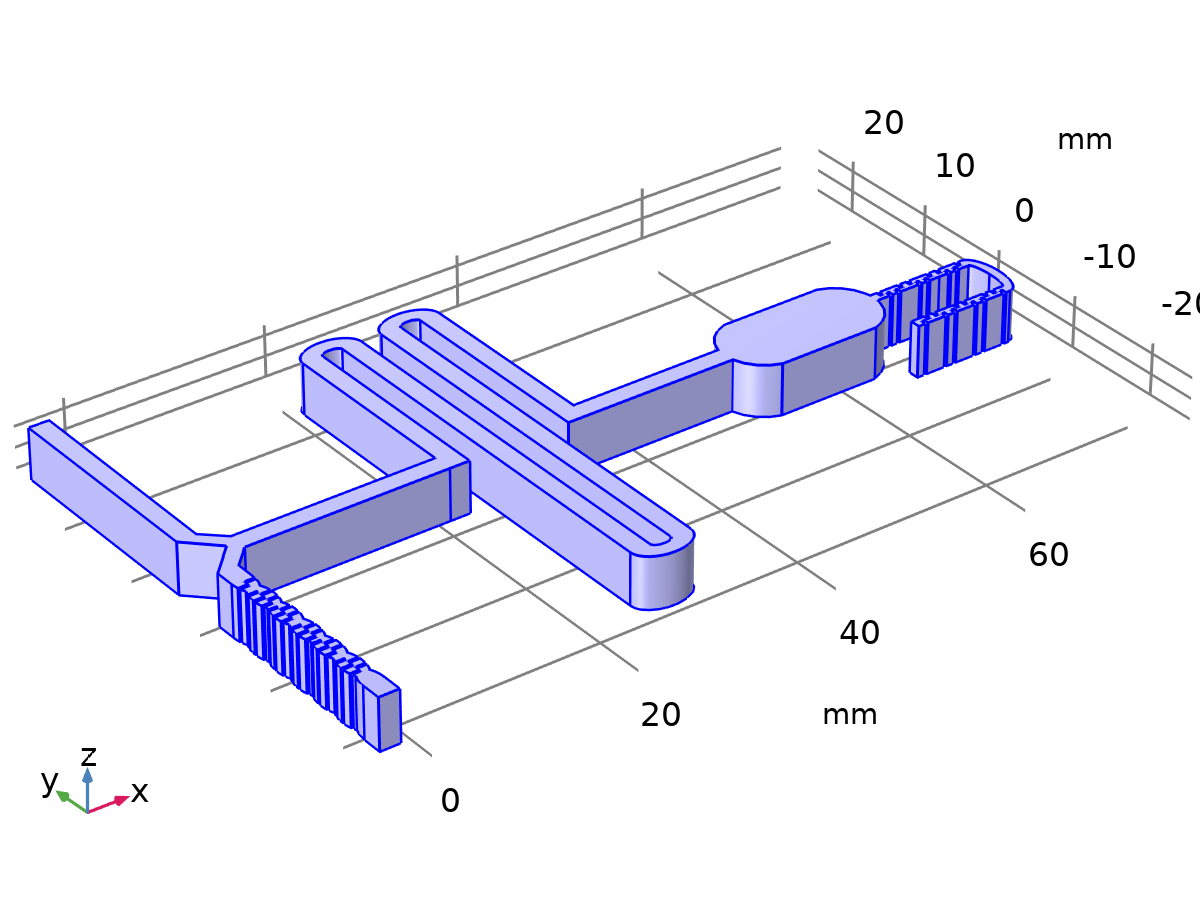
Settings

| **Description** | **Value** |
| --- | --- |
| Turbulence model type | None |

* + 1. Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** | **Details** |
| --- | --- | --- | --- | --- | --- |
| spf.Tref | model.input.Tref | K | Reference temperature | Global | Meta |
| spf.dz | 1 | m | Thickness | Domain 1 |  |
| spf.pref | 1[atm] | Pa | Reference pressure level | Domain 1 |  |
| spf.pA | p+spf.pref | Pa | Absolute pressure | Domain 1 |  |
| spf.hasWF | 0 |  | Help variable | Boundaries 1–269 |  |
| spf.dt\_CFL | 1/max(spf.maxop(sqrt(emetric\_spatial(u-d(x,TIME),v-d(y,TIME),w-d(z,TIME)))),eps) | s | Time step, CFL=1 | Global |  |
| spf.Qvd\_tot | spf.intop(spf.Qvd) | W | Total viscous dissipation | Global |  |
| spf.K\_stressx | spf.K\_stress\_tensorxx\*spf.nxmesh+spf.K\_stress\_tensorxy\*spf.nymesh+spf.K\_stress\_tensorxz\*spf.nzmesh | N/m² | Viscous force, exterior boundaries, x component | Boundaries 1–269 |  |
| spf.K\_stressy | spf.K\_stress\_tensoryx\*spf.nxmesh+spf.K\_stress\_tensoryy\*spf.nymesh+spf.K\_stress\_tensoryz\*spf.nzmesh | N/m² | Viscous force, exterior boundaries, y component | Boundaries 1–269 |  |
| spf.K\_stressz | spf.K\_stress\_tensorzx\*spf.nxmesh+spf.K\_stress\_tensorzy\*spf.nymesh+spf.K\_stress\_tensorzz\*spf.nzmesh | N/m² | Viscous force, exterior boundaries, z component | Boundaries 1–269 |  |
| spf.T\_stressx | spf.T\_stress\_tensorxx\*spf.nxmesh+spf.T\_stress\_tensorxy\*spf.nymesh+spf.T\_stress\_tensorxz\*spf.nzmesh | N/m² | Total traction, exterior boundaries, x component | Boundaries 1–269 |  |
| spf.T\_stressy | spf.T\_stress\_tensoryx\*spf.nxmesh+spf.T\_stress\_tensoryy\*spf.nymesh+spf.T\_stress\_tensoryz\*spf.nzmesh | N/m² | Total traction, exterior boundaries, y component | Boundaries 1–269 |  |
| spf.T\_stressz | spf.T\_stress\_tensorzx\*spf.nxmesh+spf.T\_stress\_tensorzy\*spf.nymesh+spf.T\_stress\_tensorzz\*spf.nzmesh | N/m² | Total traction, exterior boundaries, z component | Boundaries 1–269 |  |
| spf.K\_stress\_dx | down(spf.K\_stress\_tensorxx)\*spf.dnxmesh+down(spf.K\_stress\_tensorxy)\*spf.dnymesh+down(spf.K\_stress\_tensorxz)\*spf.dnzmesh | N/m² | Viscous force, interior boundaries, downside, x component | Boundaries 1–269 |  |
| spf.K\_stress\_dy | down(spf.K\_stress\_tensoryx)\*spf.dnxmesh+down(spf.K\_stress\_tensoryy)\*spf.dnymesh+down(spf.K\_stress\_tensoryz)\*spf.dnzmesh | N/m² | Viscous force, interior boundaries, downside, y component | Boundaries 1–269 |  |
| spf.K\_stress\_dz | down(spf.K\_stress\_tensorzx)\*spf.dnxmesh+down(spf.K\_stress\_tensorzy)\*spf.dnymesh+down(spf.K\_stress\_tensorzz)\*spf.dnzmesh | N/m² | Viscous force, interior boundaries, downside, z component | Boundaries 1–269 |  |
| spf.T\_stress\_dx | down(spf.T\_stress\_tensorxx)\*spf.dnxmesh+down(spf.T\_stress\_tensorxy)\*spf.dnymesh+down(spf.T\_stress\_tensorxz)\*spf.dnzmesh | N/m² | Total traction, interior boundaries, downside, x component | Boundaries 1–269 |  |
| spf.T\_stress\_dy | down(spf.T\_stress\_tensoryx)\*spf.dnxmesh+down(spf.T\_stress\_tensoryy)\*spf.dnymesh+down(spf.T\_stress\_tensoryz)\*spf.dnzmesh | N/m² | Total traction, interior boundaries, downside, y component | Boundaries 1–269 |  |
| spf.T\_stress\_dz | down(spf.T\_stress\_tensorzx)\*spf.dnxmesh+down(spf.T\_stress\_tensorzy)\*spf.dnymesh+down(spf.T\_stress\_tensorzz)\*spf.dnzmesh | N/m² | Total traction, interior boundaries, downside, z component | Boundaries 1–269 |  |
| spf.usePseudoTimeStepping | 0 | 1 | Help variable | Global | + operation |
| spf.localCFLvalue | 1.3^min(niterCMP,9)+if(niterCMP>=25,9\*1.3^min(-25+niterCMP,9),0)+if(niterCMP>=45,90\*1.3^min(-45+niterCMP,9),0) |  | Local CFL number | Domain 1 |  |
| spf.locCFL | CFLCMP | 1 | Local CFL number | Domain 1 |  |
| spf.geometryLengthScale | 0.0012749999999999999 | m | Geometry length scale | Domain 1 |  |
| spf.time\_step\_inv | max(sqrt(emetric\_spatial(u,v,w)\*2^if(gmg\_level<2,0,-1+gmg\_level)^2),spf.nu/spf.geometryLengthScale^2) | Hz | Inverse time step | Domain 1 |  |
| spf.tsti | nojac(spf.time\_step\_inv/spf.locCFL) | 1/s | Help variable | Domain 1 |  |
| spf.nx | dnx | 1 | Normal vector, x component | Boundaries 1–269 |  |
| spf.ny | dny | 1 | Normal vector, y component | Boundaries 1–269 |  |
| spf.nz | dnz | 1 | Normal vector, z component | Boundaries 1–269 |  |
| spf.nxmesh | dnxmesh | 1 | Normal vector, x component | Boundaries 1–269 |  |
| spf.nymesh | dnymesh | 1 | Normal vector, y component | Boundaries 1–269 |  |
| spf.nzmesh | dnzmesh | 1 | Normal vector, z component | Boundaries 1–269 |  |

* + 1. Fluid Properties 1

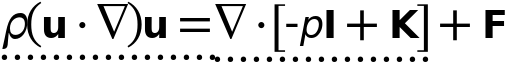


Fluid Properties 1

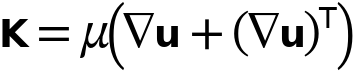
Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1: Dimension 3: All domains |

Equations







#### Fluid Properties

Settings

| **Description** | **Value** |
| --- | --- |
| Density | From material |
|  | Newtonian |
| Dynamic viscosity | From material |

#### Model Input

Settings

| **Description** | **Value** |
| --- | --- |
| Temperature | Common model input |

Used products

|  |
| --- |
| COMSOL Multiphysics |

Properties from material

| **Property** | **Material** | **Property group** |
| --- | --- | --- |
| Density | Material 1 | Basic |
| Dynamic viscosity | Material 1 | Basic |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** | **Details** |
| --- | --- | --- | --- | --- | --- |
| spf.nu | spf.mu/spf.rho | m²/s | Kinematic viscosity | Domain 1 |  |
| spf.mu | material.mu | Pa·s | Dynamic viscosity | Domain 1 | Meta |
| spf.rho | subst(material.rho,spf.fp1.minput\_temperature,spf.Trho,spf.fp1.minput\_pressure,spf.prho) | kg/m³ | Density | Domain 1 | Meta |
| spf.Trho | spf.Tref | K | Temperature for density evaluation | Domain 1 |  |
| spf.prho | spf.pref | Pa | Pressure for the evaluation of density | Domain 1 |  |
| spf.rhoref | subst(material.rho,spf.fp1.minput\_temperature,spf.Tref,spf.fp1.minput\_pressure,spf.pref) | kg/m³ | Reference density | Domain 1 | Meta |
| spf.mumat | material.mu | Pa·s | Dynamic viscosity | Domain 1 | Meta |
| spf.srijxx | ux | 1/s | Strain rate tensor, xx component | Domain 1 |  |
| spf.srijyx | 0.5\*(vx+uy) | 1/s | Strain rate tensor, yx component | Domain 1 |  |
| spf.srijzx | 0.5\*(wx+uz) | 1/s | Strain rate tensor, zx component | Domain 1 |  |
| spf.srijxy | 0.5\*(uy+vx) | 1/s | Strain rate tensor, xy component | Domain 1 |  |
| spf.srijyy | vy | 1/s | Strain rate tensor, yy component | Domain 1 |  |
| spf.srijzy | 0.5\*(wy+vz) | 1/s | Strain rate tensor, zy component | Domain 1 |  |
| spf.srijxz | 0.5\*(uz+wx) | 1/s | Strain rate tensor, xz component | Domain 1 |  |
| spf.srijyz | 0.5\*(vz+wy) | 1/s | Strain rate tensor, yz component | Domain 1 |  |
| spf.srijzz | wz | 1/s | Strain rate tensor, zz component | Domain 1 |  |
| spf.rrijxx | 0 | 1/s | Rotation rate tensor, xx component | Domain 1 |  |
| spf.rrijyx | 0.5\*(vx-uy) | 1/s | Rotation rate tensor, yx component | Domain 1 |  |
| spf.rrijzx | 0.5\*(wx-uz) | 1/s | Rotation rate tensor, zx component | Domain 1 |  |
| spf.rrijxy | 0.5\*(uy-vx) | 1/s | Rotation rate tensor, xy component | Domain 1 |  |
| spf.rrijyy | 0 | 1/s | Rotation rate tensor, yy component | Domain 1 |  |
| spf.rrijzy | 0.5\*(wy-vz) | 1/s | Rotation rate tensor, zy component | Domain 1 |  |
| spf.rrijxz | 0.5\*(uz-wx) | 1/s | Rotation rate tensor, xz component | Domain 1 |  |
| spf.rrijyz | 0.5\*(vz-wy) | 1/s | Rotation rate tensor, yz component | Domain 1 |  |
| spf.rrijzz | 0 | 1/s | Rotation rate tensor, zz component | Domain 1 |  |
| spf.sr | sqrt(2\*spf.srijxx^2+2\*spf.srijxy^2+2\*spf.srijxz^2+2\*spf.srijyx^2+2\*spf.srijyy^2+2\*spf.srijyz^2+2\*spf.srijzx^2+2\*spf.srijzy^2+2\*spf.srijzz^2+eps) | 1/s | Shear rate | Domain 1 |  |
| spf.rr | sqrt(2\*spf.rrijxx^2+2\*spf.rrijxy^2+2\*spf.rrijxz^2+2\*spf.rrijyx^2+2\*spf.rrijyy^2+2\*spf.rrijyz^2+2\*spf.rrijzx^2+2\*spf.rrijzy^2+2\*spf.rrijzz^2+eps) | 1/s | Rotation rate | Domain 1 |  |
| spf.divu | ux+vy+wz | 1/s | Divergence of velocity field | Domain 1 |  |
| spf.Fx | 0 | N/m³ | Volume force, x component | Domain 1 | + operation |
| spf.Fy | 0 | N/m³ | Volume force, y component | Domain 1 | + operation |
| spf.Fz | 0 | N/m³ | Volume force, z component | Domain 1 | + operation |
| spf.U | sqrt(u^2+v^2+w^2) | m/s | Velocity magnitude | Domain 1 |  |
| spf.vorticityx | wy-vz | 1/s | Vorticity field, x component | Domain 1 |  |
| spf.vorticityy | -wx+uz | 1/s | Vorticity field, y component | Domain 1 |  |
| spf.vorticityz | vx-uy | 1/s | Vorticity field, z component | Domain 1 |  |
| spf.vort\_magn | sqrt(spf.vorticityx^2+spf.vorticityy^2+spf.vorticityz^2) | 1/s | Vorticity magnitude | Domain 1 |  |
| spf.cellRe | 0.25\*spf.rho\*sqrt(emetric\_spatial(u-d(x,TIME),v-d(y,TIME),w-d(z,TIME))/emetric2\_spatial)/spf.mu | 1 | Cell Reynolds number | Domain 1 |  |
| spf.betaT | 0 | 1/Pa | Isothermal compressibility coefficient | Domain 1 |  |
| spf.Qm | 0 | kg/(m³·s) | Source term | Domain 1 | + operation |
| spf.Fgtotx | 0 | N/m³ | Gravity force, x component | Domain 1 | + operation |
| spf.Fgtoty | 0 | N/m³ | Gravity force, y component | Domain 1 | + operation |
| spf.Fgtotz | 0 | N/m³ | Gravity force, z component | Domain 1 | + operation |
| spf.mu\_eff | spf.mu+spf.muT | Pa·s | Dynamic viscosity | Domain 1 |  |
| spf.muT | 0 | Pa·s | Turbulent dynamic viscosity | Domain 1 |  |
| spf.T\_stress\_tensorxx | spf.K\_stress\_tensorxx-p | N/m² | Total stress tensor, xx component | Domain 1 | + operation |
| spf.T\_stress\_tensoryx | spf.K\_stress\_tensoryx | N/m² | Total stress tensor, yx component | Domain 1 | + operation |
| spf.T\_stress\_tensorzx | spf.K\_stress\_tensorzx | N/m² | Total stress tensor, zx component | Domain 1 | + operation |
| spf.T\_stress\_tensorxy | spf.K\_stress\_tensorxy | N/m² | Total stress tensor, xy component | Domain 1 | + operation |
| spf.T\_stress\_tensoryy | spf.K\_stress\_tensoryy-p | N/m² | Total stress tensor, yy component | Domain 1 | + operation |
| spf.T\_stress\_tensorzy | spf.K\_stress\_tensorzy | N/m² | Total stress tensor, zy component | Domain 1 | + operation |
| spf.T\_stress\_tensorxz | spf.K\_stress\_tensorxz | N/m² | Total stress tensor, xz component | Domain 1 | + operation |
| spf.T\_stress\_tensoryz | spf.K\_stress\_tensoryz | N/m² | Total stress tensor, yz component | Domain 1 | + operation |
| spf.T\_stress\_tensorzz | spf.K\_stress\_tensorzz-p | N/m² | Total stress tensor, zz component | Domain 1 | + operation |
| spf.K\_stress\_tensorxx | 2\*spf.mu\_eff\*ux | N/m² | Viscous stress tensor, xx component | Domain 1 | + operation |
| spf.K\_stress\_tensoryx | spf.mu\_eff\*(vx+uy) | N/m² | Viscous stress tensor, yx component | Domain 1 | + operation |
| spf.K\_stress\_tensorzx | spf.mu\_eff\*(wx+uz) | N/m² | Viscous stress tensor, zx component | Domain 1 | + operation |
| spf.K\_stress\_tensorxy | spf.mu\_eff\*(uy+vx) | N/m² | Viscous stress tensor, xy component | Domain 1 | + operation |
| spf.K\_stress\_tensoryy | 2\*spf.mu\_eff\*vy | N/m² | Viscous stress tensor, yy component | Domain 1 | + operation |
| spf.K\_stress\_tensorzy | spf.mu\_eff\*(wy+vz) | N/m² | Viscous stress tensor, zy component | Domain 1 | + operation |
| spf.K\_stress\_tensorxz | spf.mu\_eff\*(uz+wx) | N/m² | Viscous stress tensor, xz component | Domain 1 | + operation |
| spf.K\_stress\_tensoryz | spf.mu\_eff\*(vz+wy) | N/m² | Viscous stress tensor, yz component | Domain 1 | + operation |
| spf.K\_stress\_tensorzz | 2\*spf.mu\_eff\*wz | N/m² | Viscous stress tensor, zz component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testxx | 2\*spf.mu\_eff\*test(ux) | N/m² | Viscous stress tensor test, xx component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testyx | spf.mu\_eff\*(test(vx)+test(uy)) | N/m² | Viscous stress tensor test, yx component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testzx | spf.mu\_eff\*(test(wx)+test(uz)) | N/m² | Viscous stress tensor test, zx component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testxy | spf.mu\_eff\*(test(uy)+test(vx)) | N/m² | Viscous stress tensor test, xy component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testyy | 2\*spf.mu\_eff\*test(vy) | N/m² | Viscous stress tensor test, yy component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testzy | spf.mu\_eff\*(test(wy)+test(vz)) | N/m² | Viscous stress tensor test, zy component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testxz | spf.mu\_eff\*(test(uz)+test(wx)) | N/m² | Viscous stress tensor test, xz component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testyz | spf.mu\_eff\*(test(vz)+test(wy)) | N/m² | Viscous stress tensor test, yz component | Domain 1 | + operation |
| spf.K\_stress\_tensor\_testzz | 2\*spf.mu\_eff\*test(wz) | N/m² | Viscous stress tensor test, zz component | Domain 1 | + operation |
| spf.upwind\_helpx | u-d(x,TIME) | m/s | Upwind term, x component | Domain 1 | + operation |
| spf.upwind\_helpy | v-d(y,TIME) | m/s | Upwind term, y component | Domain 1 | + operation |
| spf.upwind\_helpz | w-d(z,TIME) | m/s | Upwind term, z component | Domain 1 | + operation |
| spf.tau\_vdxx | 2\*spf.mu\*spf.srijxx | Pa | Viscous stress tensor, xx component | Domain 1 | + operation |
| spf.tau\_vdyx | 2\*spf.mu\*spf.srijyx | Pa | Viscous stress tensor, yx component | Domain 1 | + operation |
| spf.tau\_vdzx | 2\*spf.mu\*spf.srijzx | Pa | Viscous stress tensor, zx component | Domain 1 | + operation |
| spf.tau\_vdxy | 2\*spf.mu\*spf.srijxy | Pa | Viscous stress tensor, xy component | Domain 1 | + operation |
| spf.tau\_vdyy | 2\*spf.mu\*spf.srijyy | Pa | Viscous stress tensor, yy component | Domain 1 | + operation |
| spf.tau\_vdzy | 2\*spf.mu\*spf.srijzy | Pa | Viscous stress tensor, zy component | Domain 1 | + operation |
| spf.tau\_vdxz | 2\*spf.mu\*spf.srijxz | Pa | Viscous stress tensor, xz component | Domain 1 | + operation |
| spf.tau\_vdyz | 2\*spf.mu\*spf.srijyz | Pa | Viscous stress tensor, yz component | Domain 1 | + operation |
| spf.tau\_vdzz | 2\*spf.mu\*spf.srijzz | Pa | Viscous stress tensor, zz component | Domain 1 | + operation |
| spf.Qvd | spf.tau\_vdxx\*ux+spf.tau\_vdxy\*uy+spf.tau\_vdxz\*uz+spf.tau\_vdyx\*vx+spf.tau\_vdyy\*vy+spf.tau\_vdyz\*vz+spf.tau\_vdzx\*wx+spf.tau\_vdzy\*wy+spf.tau\_vdzz\*wz | W/m³ | Viscous dissipation | Domain 1 | + operation |
| spf.epsilon\_p | 1 | 1 | Porosity | Domain 1 |  |
| spf.Fst\_tensorxx | 0 | N/m² | Surface tension force, xx component | Domain 1 | + operation |
| spf.Fst\_tensoryx | 0 | N/m² | Surface tension force, yx component | Domain 1 | + operation |
| spf.Fst\_tensorzx | 0 | N/m² | Surface tension force, zx component | Domain 1 | + operation |
| spf.Fst\_tensorxy | 0 | N/m² | Surface tension force, xy component | Domain 1 | + operation |
| spf.Fst\_tensoryy | 0 | N/m² | Surface tension force, yy component | Domain 1 | + operation |
| spf.Fst\_tensorzy | 0 | N/m² | Surface tension force, zy component | Domain 1 | + operation |
| spf.Fst\_tensorxz | 0 | N/m² | Surface tension force, xz component | Domain 1 | + operation |
| spf.Fst\_tensoryz | 0 | N/m² | Surface tension force, yz component | Domain 1 | + operation |
| spf.Fst\_tensorzz | 0 | N/m² | Surface tension force, zz component | Domain 1 | + operation |
| spf.continuityEquation | spf.rho\*spf.divu | kg/(m³·s) | Continuity equation | Domain 1 |  |
| spf.contCoeff | spf.rho | kg/m³ | Help variable | Domain 1 |  |
| spf.res\_u | px+spf.rho\*u\*ux+spf.rho\*v\*uy+spf.rho\*w\*uz-(d(2\*ux,x)+d(uy+vx,y)+d(uz+wx,z))\*spf.mu-spf.Fx | N/m³ | Equation residual | Domain 1 |  |
| spf.res\_v | spf.rho\*u\*vx+py+spf.rho\*v\*vy+spf.rho\*w\*vz-(d(vx+uy,x)+d(2\*vy,y)+d(vz+wy,z))\*spf.mu-spf.Fy | N/m³ | Equation residual | Domain 1 |  |
| spf.res\_w | spf.rho\*u\*wx+spf.rho\*v\*wy+pz+spf.rho\*w\*wz-(d(wx+uz,x)+d(wy+vz,y)+d(2\*wz,z))\*spf.mu-spf.Fz | N/m³ | Equation residual | Domain 1 |  |
| spf.res\_p | spf.rho\*spf.divu | kg/(m³·s) | Pressure equation residual | Domain 1 |  |

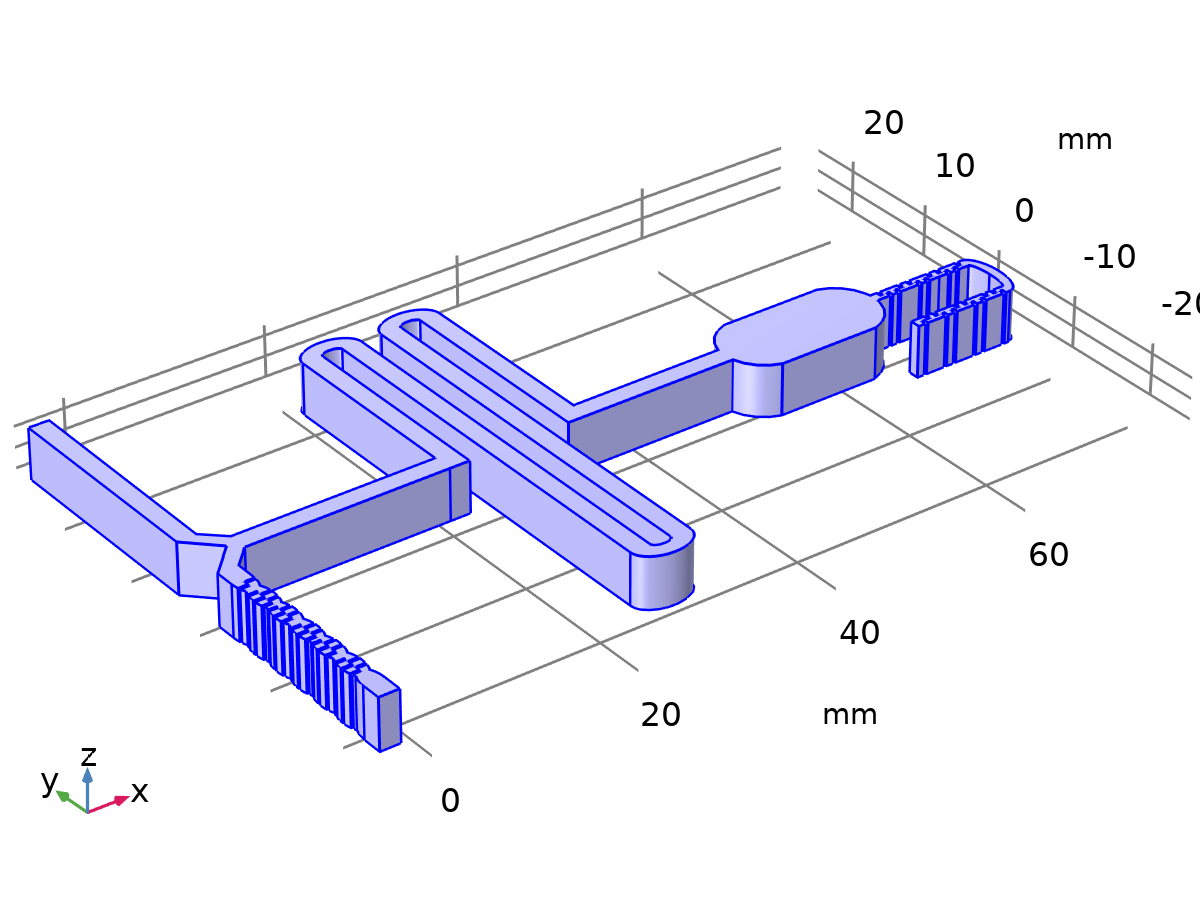
#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| u | Lagrange (Quadratic) | m/s | Velocity field, x component | Spatial | Domain 1 |
| v | Lagrange (Quadratic) | m/s | Velocity field, y component | Spatial | Domain 1 |
| w | Lagrange (Quadratic) | m/s | Velocity field, z component | Spatial | Domain 1 |
| p | Lagrange (Linear) | Pa | Pressure | Spatial | Domain 1 |

#### Weak Expressions

| **Weak expression** | **Integration order** | **Integration frame** | **Selection** |
| --- | --- | --- | --- |
| (p-spf.K\_stress\_tensorxx)\*test(ux)-spf.K\_stress\_tensorxy\*test(uy)-spf.K\_stress\_tensorxz\*test(uz)-spf.K\_stress\_tensoryx\*test(vx)+(p-spf.K\_stress\_tensoryy)\*test(vy)-spf.K\_stress\_tensoryz\*test(vz)-spf.K\_stress\_tensorzx\*test(wx)-spf.K\_stress\_tensorzy\*test(wy)+(p-spf.K\_stress\_tensorzz)\*test(wz) | 4 | Spatial | Domain 1 |
| spf.Fx\*test(u)+spf.Fy\*test(v)+spf.Fz\*test(w) | 4 | Spatial | Domain 1 |
| spf.rho\*(-(d(u,x)\*u+d(u,y)\*v+d(u,z)\*w)\*test(u)-(d(v,x)\*u+d(v,y)\*v+d(v,z)\*w)\*test(v)-(d(w,x)\*u+d(w,y)\*v+d(w,z)\*w)\*test(w)) | 4 | Spatial | Domain 1 |
| -spf.continuityEquation\*test(p) | 4 | Spatial | Domain 1 |
| spf.streamlinens | 4 | Spatial | Domain 1 |
| spf.crosswindns | 4 | Spatial | Domain 1 |
| (spf.usePseudoTimeStepping>0)\*spf.rho\*spf.tsti\*(-(u-nojac(u))\*test(u)-(v-nojac(v))\*test(v)-(w-nojac(w))\*test(w)) | 4 | Spatial | Domain 1 |

* + 1. Initial Values 1



Initial Values 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1: Dimension 3: All domains |

#### Initial Values

Settings

| **Description** | **Value** |
| --- | --- |
| Velocity field, x component | 0 |
| Velocity field, y component | 0 |
| Velocity field, z component | 0 |
| Pressure | 0 |

#### Coordinate System Selection

Settings

| **Description** | **Value** |
| --- | --- |
| Coordinate system | Global coordinate system |

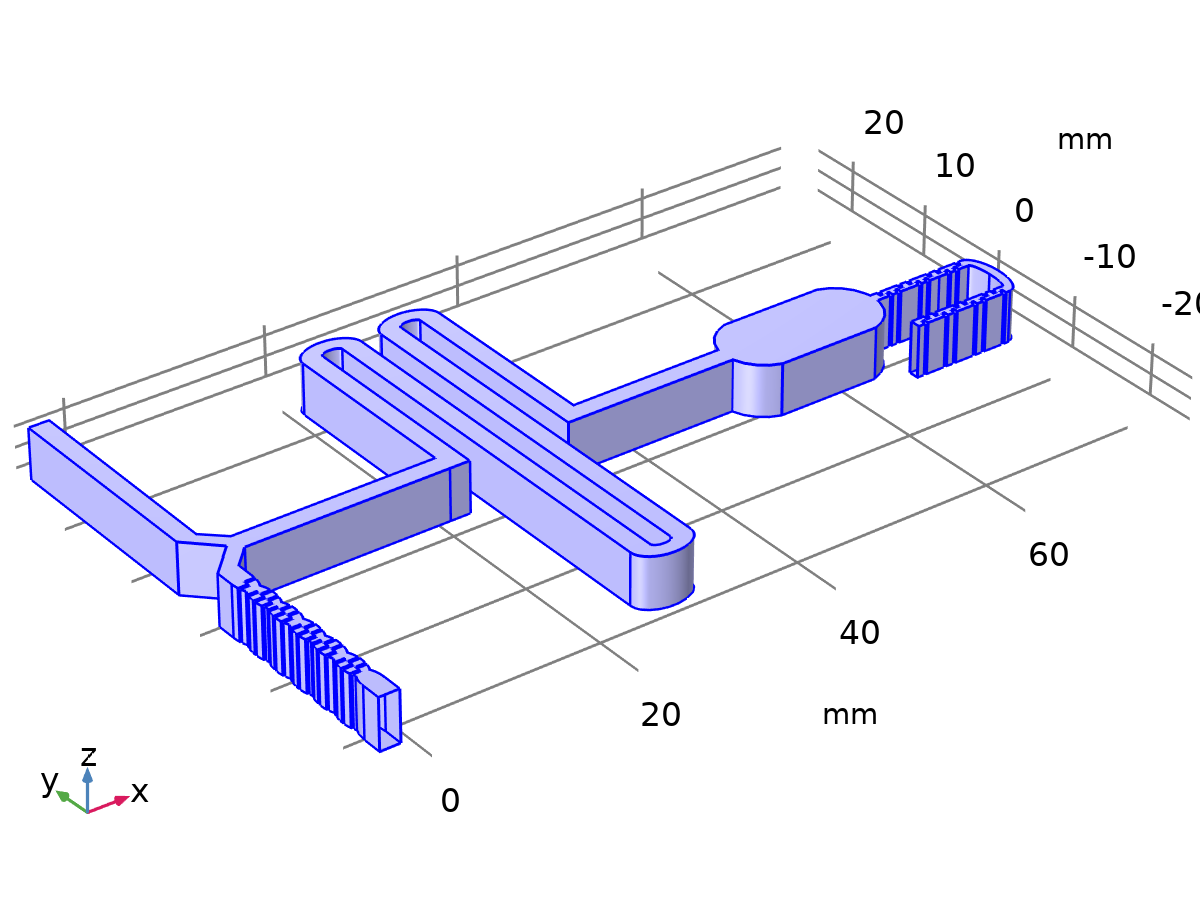
Used products

|  |
| --- |
| COMSOL Multiphysics |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.u\_initx | 0 | m/s | Velocity field, x component | Domain 1 |
| spf.u\_inity | 0 | m/s | Velocity field, y component | Domain 1 |
| spf.u\_initz | 0 | m/s | Velocity field, z component | Domain 1 |
| spf.p\_init | 0 | Pa | Pressure | Domain 1 |

* + 1. Wall 1



Wall 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Geometry geom1: Dimension 2: All boundaries |

Equations



#### Boundary Condition

Settings

| **Description** | **Value** |
| --- | --- |
| Wall condition | No slip |

#### Wall Movement

Settings

| **Description** | **Value** |
| --- | --- |
| Translational velocity | Automatic from frame |
| Sliding wall | Off |

Used products

|  |
| --- |
| COMSOL Multiphysics |

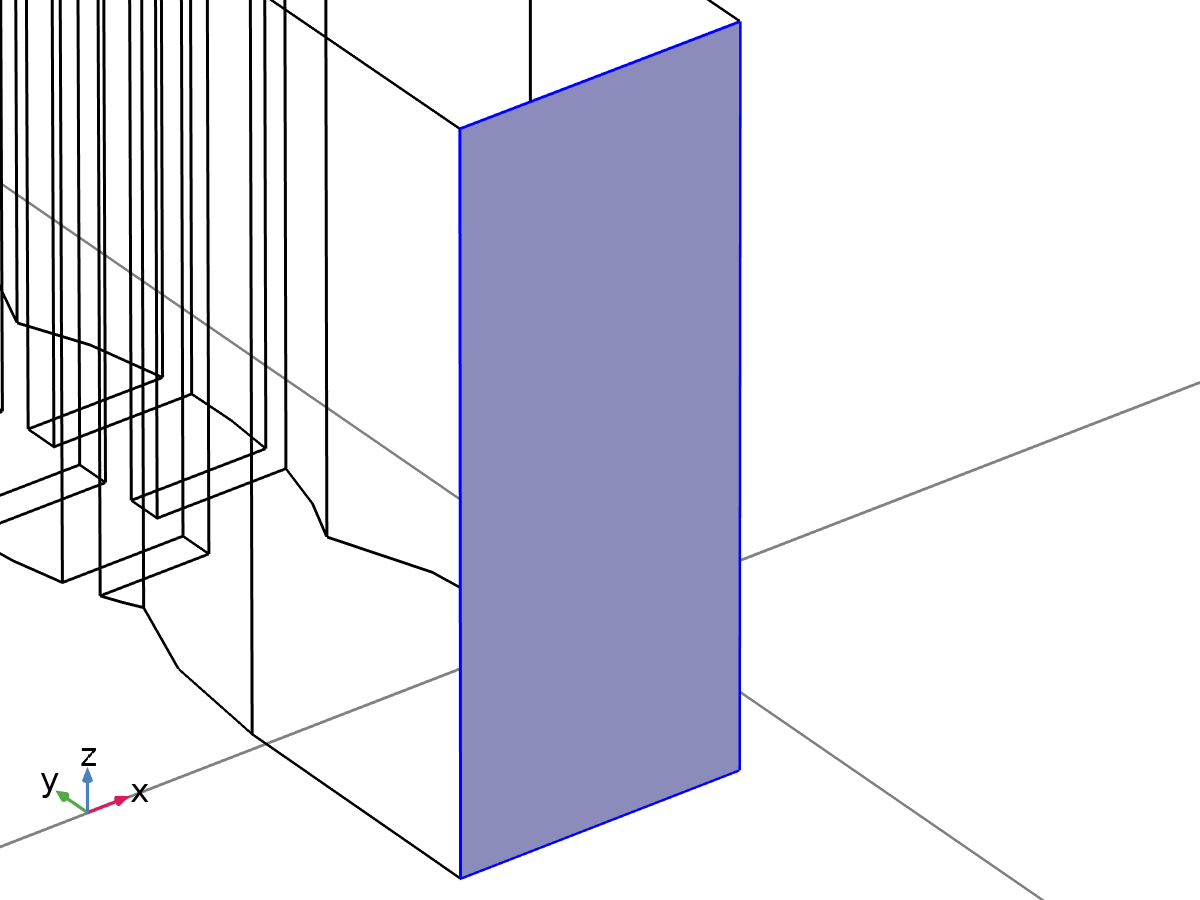
#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** | **Details** |
| --- | --- | --- | --- | --- | --- |
| spf.ubndx | spf.utrx+spf.usx | m/s | Velocity at boundary, x component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.ubndy | spf.utry+spf.usy | m/s | Velocity at boundary, y component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.ubndz | spf.utrz+spf.usz | m/s | Velocity at boundary, z component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.usx | 0 | m/s | Velocity of sliding wall, x component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.usy | 0 | m/s | Velocity of sliding wall, y component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.usz | 0 | m/s | Velocity of sliding wall, z component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.utrx | 0 | m/s | Velocity of moving wall, x component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.utry | 0 | m/s | Velocity of moving wall, y component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.utrz | 0 | m/s | Velocity of moving wall, z component | Boundaries 1, 3–20, 22–163, 165–269 |  |
| spf.uLeakagex | 0 | m/s | Leakage velocity, x component | Boundaries 1, 3–20, 22–163, 165–269 | + operation |
| spf.uLeakagey | 0 | m/s | Leakage velocity, y component | Boundaries 1, 3–20, 22–163, 165–269 | + operation |
| spf.uLeakagez | 0 | m/s | Leakage velocity, z component | Boundaries 1, 3–20, 22–163, 165–269 | + operation |
| spf.noSlipWall | 1 | 1 | Help variable | Boundaries 1, 3–20, 22–163, 165–269 |  |

#### Constraints

| **Constraint** | **Constraint force** | **Shape function** | **Selection** | **Details** |
| --- | --- | --- | --- | --- |
| -u+spf.ubndx+spf.uLeakagex | test(-u) | Lagrange (Quadratic) | Boundaries 1, 3–20, 22–163, 165–269 | Elemental |
| -v+spf.ubndy+spf.uLeakagey | test(-v) | Lagrange (Quadratic) | Boundaries 1, 3–20, 22–163, 165–269 | Elemental |
| -w+spf.ubndz+spf.uLeakagez | test(-w) | Lagrange (Quadratic) | Boundaries 1, 3–20, 22–163, 165–269 | Elemental |

* + 1. Inlet 1



Inlet 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Geometry geom1: Dimension 2: Boundary 2 |

Equations





#### Boundary Condition

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Fully developed flow |
| Apply condition on each disjoint selection separately | On |

#### Fully Developed Flow

Settings

| **Description** | **Value** |
| --- | --- |
| Fully developed flow option | Average velocity |
| Average velocity | uL |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.nu | spf.mu/spf.rho | m²/s | Kinematic viscosity | Boundary 2 |
| spf.KStressn\_avx | spf.K\_stress\_tensorxx\*spf.nxmesh+spf.K\_stress\_tensorxy\*spf.nymesh+spf.K\_stress\_tensorxz\*spf.nzmesh | N/m² | Average viscous stress, x component | Boundary 2 |
| spf.KStressn\_avy | spf.K\_stress\_tensoryx\*spf.nxmesh+spf.K\_stress\_tensoryy\*spf.nymesh+spf.K\_stress\_tensoryz\*spf.nzmesh | N/m² | Average viscous stress, y component | Boundary 2 |
| spf.KStressn\_avz | spf.K\_stress\_tensorzx\*spf.nxmesh+spf.K\_stress\_tensorzy\*spf.nymesh+spf.K\_stress\_tensorzz\*spf.nzmesh | N/m² | Average viscous stress, z component | Boundary 2 |
| spf.KStressTestn\_avx | spf.K\_stress\_tensor\_testxx\*spf.nxmesh+spf.K\_stress\_tensor\_testxy\*spf.nymesh+spf.K\_stress\_tensor\_testxz\*spf.nzmesh | N/m² | Average viscous stress, x component | Boundary 2 |
| spf.KStressTestn\_avy | spf.K\_stress\_tensor\_testyx\*spf.nxmesh+spf.K\_stress\_tensor\_testyy\*spf.nymesh+spf.K\_stress\_tensor\_testyz\*spf.nzmesh | N/m² | Average viscous stress, y component | Boundary 2 |
| spf.KStressTestn\_avz | spf.K\_stress\_tensor\_testzx\*spf.nxmesh+spf.K\_stress\_tensor\_testzy\*spf.nymesh+spf.K\_stress\_tensor\_testzz\*spf.nzmesh | N/m² | Average viscous stress, z component | Boundary 2 |
| spf.ujumpx | spf.ut\_herex-spf.ut\_therex | m/s | Velocity jump, x component | Boundary 2 |
| spf.ujumpy | spf.ut\_herey-spf.ut\_therey | m/s | Velocity jump, y component | Boundary 2 |
| spf.ujumpz | spf.ut\_herez-spf.ut\_therez | m/s | Velocity jump, z component | Boundary 2 |
| spf.meshVol | meshvol\_spatial | m² |  | Boundary 2 |
| spf.meshVolInt | down(meshvol\_spatial) | m³ | Volume of interior mesh element | Boundary 2 |
| spf.c\_here | 96\*nojac(down((spf.mu+spf.muT)/spf.epsilon\_p))\*spf.meshVol/spf.meshVolInt | Pa·s/m | Intermediate variable | Boundary 2 |
| spf.sigma\_dg\_ns | 4\*spf.c\_here | Pa·s/m |  | Boundary 2 |
| spf.un\_here | u\*nojac(spf.nxmesh)+v\*nojac(spf.nymesh)+w\*nojac(spf.nzmesh) | m/s | Intermediate variable | Boundary 2 |
| spf.ut\_herex | u-spf.un\_here\*nojac(spf.nxmesh) | m/s | Intermediate variable, x component | Boundary 2 |
| spf.ut\_herey | v-spf.un\_here\*nojac(spf.nymesh) | m/s | Intermediate variable, y component | Boundary 2 |
| spf.ut\_herez | w-spf.un\_here\*nojac(spf.nzmesh) | m/s | Intermediate variable, z component | Boundary 2 |
| spf.un\_there | 0 | m/s | Intermediate variable | Boundary 2 |
| spf.ut\_therex | -spf.un\_there\*nojac(spf.nxmesh) | m/s | Intermediate variable, x component | Boundary 2 |
| spf.ut\_therey | -spf.un\_there\*nojac(spf.nymesh) | m/s | Intermediate variable, y component | Boundary 2 |
| spf.ut\_therez | -spf.un\_there\*nojac(spf.nzmesh) | m/s | Intermediate variable, z component | Boundary 2 |
| spf.unTestx | (test(u)\*spf.nxmesh+test(v)\*spf.nymesh+test(w)\*spf.nzmesh)\*spf.nxmesh | m/s |  | Boundary 2 |
| spf.unTesty | (test(u)\*spf.nxmesh+test(v)\*spf.nymesh+test(w)\*spf.nzmesh)\*spf.nymesh | m/s |  | Boundary 2 |
| spf.unTestz | (test(u)\*spf.nxmesh+test(v)\*spf.nymesh+test(w)\*spf.nzmesh)\*spf.nzmesh | m/s |  | Boundary 2 |
| spf.d | 1 |  | Length | Boundary 2 |
| spf.inl1.Uavfdf | uL | m/s | Average velocity | Global |
| spf.inl1.dz | spf.dz | m | Channel thickness | Boundary 2 |
| spf.inl1.pHydroCompensation | 0 | Pa | Hydrostatic pressure | Global |
| spf.inl1.L | 10\*sqrt(spf.inl1.intop(1)) | m | Entrance length | Global |
| spf.inl1.volumeFlowRate | spf.inl1.intop(u\*spf.nxmesh+v\*spf.nymesh+w\*spf.nzmesh) | m³/s | Outward volume flow rate across feature selection | Global |
| spf.inl1.massFlowRate | spf.inl1.intop(spf.rho\*(u\*spf.nxmesh+v\*spf.nymesh+w\*spf.nzmesh)) | kg/s | Outward mass flow rate across feature selection | Global |
| spf.inl1.pAverage | spf.inl1.aveop(p) | Pa | Pressure average over feature selection | Global |
| spf.inl1.Vinlfdf | -spf.inl1.volumeFlowRate | m³/s | Boundary integral of velocity | Global |
| spf.inl1.Area | spf.inl1.intop(spf.d) | m² | Boundary area | Global |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| spf.inl1.Pinlfdf | ODE | Pa | Help ode variable for fully developed flow |  | Global |

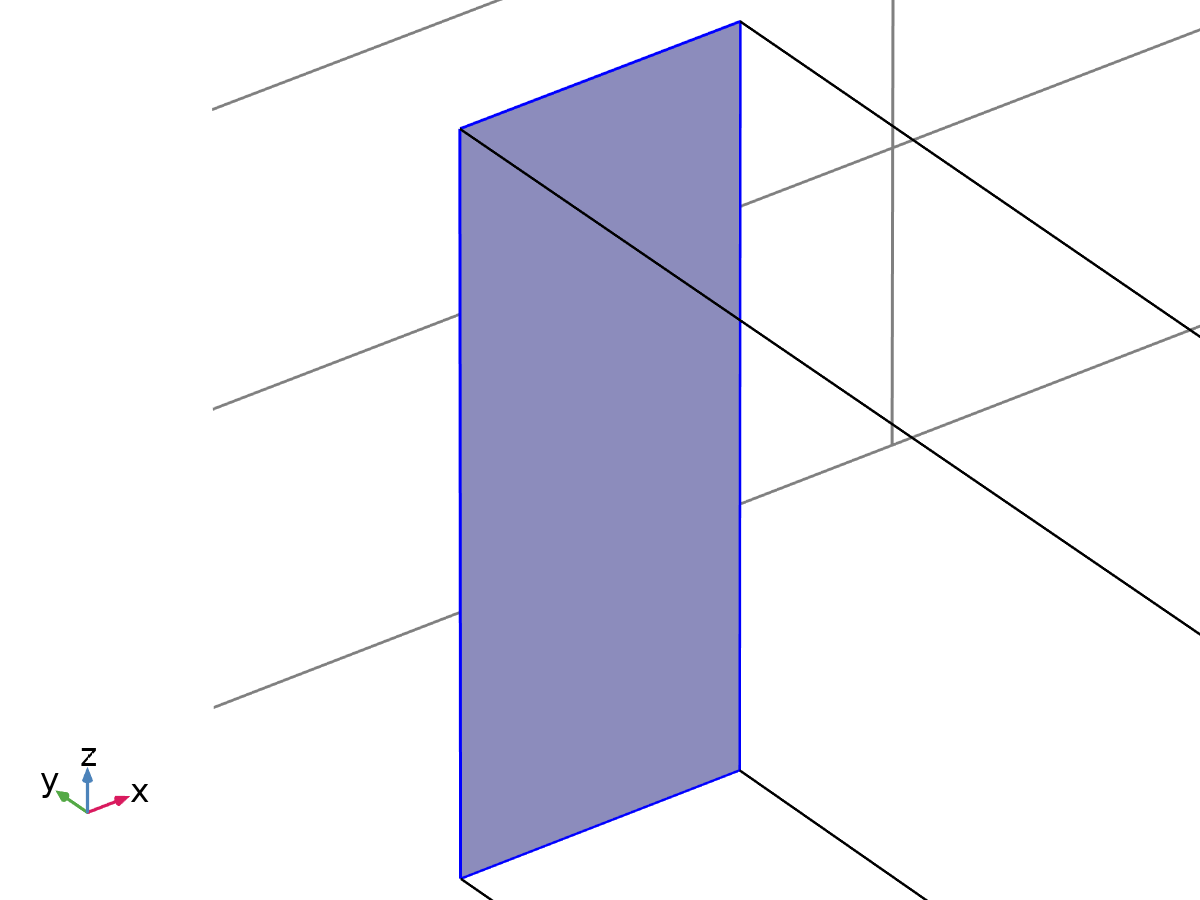
#### Weak Expressions

| **Weak expression** | **Integration order** | **Integration frame** | **Selection** |
| --- | --- | --- | --- |
| spf.KStressn\_avx\*test(spf.ut\_herex)+spf.KStressn\_avy\*test(spf.ut\_herey)+spf.KStressn\_avz\*test(spf.ut\_herez)+spf.KStressTestn\_avx\*spf.ujumpx+spf.KStressTestn\_avy\*spf.ujumpy+spf.KStressTestn\_avz\*spf.ujumpz-spf.sigma\_dg\_ns\*spf.ujumpx\*test(spf.ut\_herex)-spf.sigma\_dg\_ns\*spf.ujumpy\*test(spf.ut\_herey)-spf.sigma\_dg\_ns\*spf.ujumpz\*test(spf.ut\_herez) | 4 | Spatial | Boundary 2 |
| ((-2\*spf.mu\_eff\*uTx/spf.epsilon\_p+p)\*dtang(spf.unTestx,x)-spf.mu\_eff\*(uTy+vTx)\*dtang(spf.unTesty,x)/spf.epsilon\_p-spf.mu\_eff\*(uTz+wTx)\*dtang(spf.unTestz,x)/spf.epsilon\_p-spf.mu\_eff\*(uTy+vTx)\*dtang(spf.unTestx,y)/spf.epsilon\_p+(-2\*spf.mu\_eff\*vTy/spf.epsilon\_p+p)\*dtang(spf.unTesty,y)-spf.mu\_eff\*(vTz+wTy)\*dtang(spf.unTestz,y)/spf.epsilon\_p-spf.mu\_eff\*(uTz+wTx)\*dtang(spf.unTestx,z)/spf.epsilon\_p-spf.mu\_eff\*(vTz+wTy)\*dtang(spf.unTesty,z)/spf.epsilon\_p+(-2\*spf.mu\_eff\*wTz/spf.epsilon\_p+p)\*dtang(spf.unTestz,z))\*spf.inl1.L-(spf.nxmesh\*test(u)+spf.nymesh\*test(v)+spf.nzmesh\*test(w))\*spf.inl1.Pinlfdf | 4 | Spatial | Boundary 2 |
| (spf.inl1.Vinlfdf-spf.inl1.Area\*spf.inl1.Uavfdf)\*test(spf.inl1.Pinlfdf) | 4 |  | Global |

#### Constraints

| **Constraint** | **Constraint force** | **Shape function** | **Selection** | **Details** |
| --- | --- | --- | --- | --- |
| -u+spf.ubndx | test(-u) | Lagrange (Quadratic) | Edges 1, 3, 5, 395 | Elemental |
| -v+spf.ubndy | test(-v) | Lagrange (Quadratic) | Edges 1, 3, 5, 395 | Elemental |
| -w+spf.ubndz | test(-w) | Lagrange (Quadratic) | Edges 1, 3, 5, 395 | Elemental |

* + 1. Inlet 2



Inlet 2

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Geometry geom1: Dimension 2: Boundary 21 |

Equations





#### Boundary Condition

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Fully developed flow |
| Apply condition on each disjoint selection separately | On |

#### Fully Developed Flow

Settings

| **Description** | **Value** |
| --- | --- |
| Fully developed flow option | Average velocity |
| Average velocity | uR |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.nu | spf.mu/spf.rho | m²/s | Kinematic viscosity | Boundary 21 |
| spf.KStressn\_avx | spf.K\_stress\_tensorxx\*spf.nxmesh+spf.K\_stress\_tensorxy\*spf.nymesh+spf.K\_stress\_tensorxz\*spf.nzmesh | N/m² | Average viscous stress, x component | Boundary 21 |
| spf.KStressn\_avy | spf.K\_stress\_tensoryx\*spf.nxmesh+spf.K\_stress\_tensoryy\*spf.nymesh+spf.K\_stress\_tensoryz\*spf.nzmesh | N/m² | Average viscous stress, y component | Boundary 21 |
| spf.KStressn\_avz | spf.K\_stress\_tensorzx\*spf.nxmesh+spf.K\_stress\_tensorzy\*spf.nymesh+spf.K\_stress\_tensorzz\*spf.nzmesh | N/m² | Average viscous stress, z component | Boundary 21 |
| spf.KStressTestn\_avx | spf.K\_stress\_tensor\_testxx\*spf.nxmesh+spf.K\_stress\_tensor\_testxy\*spf.nymesh+spf.K\_stress\_tensor\_testxz\*spf.nzmesh | N/m² | Average viscous stress, x component | Boundary 21 |
| spf.KStressTestn\_avy | spf.K\_stress\_tensor\_testyx\*spf.nxmesh+spf.K\_stress\_tensor\_testyy\*spf.nymesh+spf.K\_stress\_tensor\_testyz\*spf.nzmesh | N/m² | Average viscous stress, y component | Boundary 21 |
| spf.KStressTestn\_avz | spf.K\_stress\_tensor\_testzx\*spf.nxmesh+spf.K\_stress\_tensor\_testzy\*spf.nymesh+spf.K\_stress\_tensor\_testzz\*spf.nzmesh | N/m² | Average viscous stress, z component | Boundary 21 |
| spf.ujumpx | spf.ut\_herex-spf.ut\_therex | m/s | Velocity jump, x component | Boundary 21 |
| spf.ujumpy | spf.ut\_herey-spf.ut\_therey | m/s | Velocity jump, y component | Boundary 21 |
| spf.ujumpz | spf.ut\_herez-spf.ut\_therez | m/s | Velocity jump, z component | Boundary 21 |
| spf.meshVol | meshvol\_spatial | m² |  | Boundary 21 |
| spf.meshVolInt | down(meshvol\_spatial) | m³ | Volume of interior mesh element | Boundary 21 |
| spf.c\_here | 96\*nojac(down((spf.mu+spf.muT)/spf.epsilon\_p))\*spf.meshVol/spf.meshVolInt | Pa·s/m | Intermediate variable | Boundary 21 |
| spf.sigma\_dg\_ns | 4\*spf.c\_here | Pa·s/m |  | Boundary 21 |
| spf.un\_here | u\*nojac(spf.nxmesh)+v\*nojac(spf.nymesh)+w\*nojac(spf.nzmesh) | m/s | Intermediate variable | Boundary 21 |
| spf.ut\_herex | u-spf.un\_here\*nojac(spf.nxmesh) | m/s | Intermediate variable, x component | Boundary 21 |
| spf.ut\_herey | v-spf.un\_here\*nojac(spf.nymesh) | m/s | Intermediate variable, y component | Boundary 21 |
| spf.ut\_herez | w-spf.un\_here\*nojac(spf.nzmesh) | m/s | Intermediate variable, z component | Boundary 21 |
| spf.un\_there | 0 | m/s | Intermediate variable | Boundary 21 |
| spf.ut\_therex | -spf.un\_there\*nojac(spf.nxmesh) | m/s | Intermediate variable, x component | Boundary 21 |
| spf.ut\_therey | -spf.un\_there\*nojac(spf.nymesh) | m/s | Intermediate variable, y component | Boundary 21 |
| spf.ut\_therez | -spf.un\_there\*nojac(spf.nzmesh) | m/s | Intermediate variable, z component | Boundary 21 |
| spf.unTestx | (test(u)\*spf.nxmesh+test(v)\*spf.nymesh+test(w)\*spf.nzmesh)\*spf.nxmesh | m/s |  | Boundary 21 |
| spf.unTesty | (test(u)\*spf.nxmesh+test(v)\*spf.nymesh+test(w)\*spf.nzmesh)\*spf.nymesh | m/s |  | Boundary 21 |
| spf.unTestz | (test(u)\*spf.nxmesh+test(v)\*spf.nymesh+test(w)\*spf.nzmesh)\*spf.nzmesh | m/s |  | Boundary 21 |
| spf.d | 1 |  | Length | Boundary 21 |
| spf.inl2.Uavfdf | uR | m/s | Average velocity | Global |
| spf.inl2.dz | spf.dz | m | Channel thickness | Boundary 21 |
| spf.inl2.pHydroCompensation | 0 | Pa | Hydrostatic pressure | Global |
| spf.inl2.L | 10\*sqrt(spf.inl2.intop(1)) | m | Entrance length | Global |
| spf.inl2.volumeFlowRate | spf.inl2.intop(u\*spf.nxmesh+v\*spf.nymesh+w\*spf.nzmesh) | m³/s | Outward volume flow rate across feature selection | Global |
| spf.inl2.massFlowRate | spf.inl2.intop(spf.rho\*(u\*spf.nxmesh+v\*spf.nymesh+w\*spf.nzmesh)) | kg/s | Outward mass flow rate across feature selection | Global |
| spf.inl2.pAverage | spf.inl2.aveop(p) | Pa | Pressure average over feature selection | Global |
| spf.inl2.Vinlfdf | -spf.inl2.volumeFlowRate | m³/s | Boundary integral of velocity | Global |
| spf.inl2.Area | spf.inl2.intop(spf.d) | m² | Boundary area | Global |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| spf.inl2.Pinlfdf | ODE | Pa | Help ode variable for fully developed flow |  | Global |

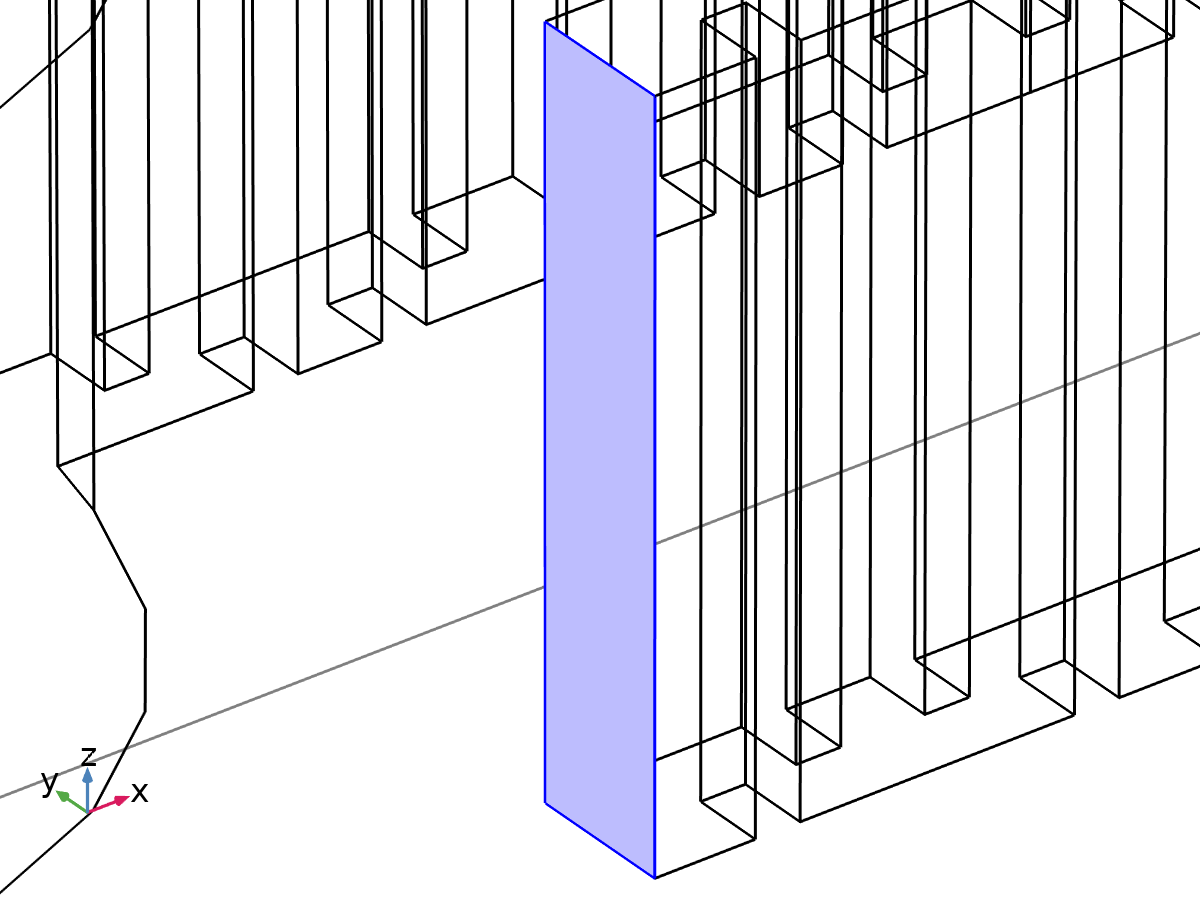
#### Weak Expressions

| **Weak expression** | **Integration order** | **Integration frame** | **Selection** |
| --- | --- | --- | --- |
| spf.KStressn\_avx\*test(spf.ut\_herex)+spf.KStressn\_avy\*test(spf.ut\_herey)+spf.KStressn\_avz\*test(spf.ut\_herez)+spf.KStressTestn\_avx\*spf.ujumpx+spf.KStressTestn\_avy\*spf.ujumpy+spf.KStressTestn\_avz\*spf.ujumpz-spf.sigma\_dg\_ns\*spf.ujumpx\*test(spf.ut\_herex)-spf.sigma\_dg\_ns\*spf.ujumpy\*test(spf.ut\_herey)-spf.sigma\_dg\_ns\*spf.ujumpz\*test(spf.ut\_herez) | 4 | Spatial | Boundary 21 |
| ((-2\*spf.mu\_eff\*uTx/spf.epsilon\_p+p)\*dtang(spf.unTestx,x)-spf.mu\_eff\*(uTy+vTx)\*dtang(spf.unTesty,x)/spf.epsilon\_p-spf.mu\_eff\*(uTz+wTx)\*dtang(spf.unTestz,x)/spf.epsilon\_p-spf.mu\_eff\*(uTy+vTx)\*dtang(spf.unTestx,y)/spf.epsilon\_p+(-2\*spf.mu\_eff\*vTy/spf.epsilon\_p+p)\*dtang(spf.unTesty,y)-spf.mu\_eff\*(vTz+wTy)\*dtang(spf.unTestz,y)/spf.epsilon\_p-spf.mu\_eff\*(uTz+wTx)\*dtang(spf.unTestx,z)/spf.epsilon\_p-spf.mu\_eff\*(vTz+wTy)\*dtang(spf.unTesty,z)/spf.epsilon\_p+(-2\*spf.mu\_eff\*wTz/spf.epsilon\_p+p)\*dtang(spf.unTestz,z))\*spf.inl2.L-(spf.nxmesh\*test(u)+spf.nymesh\*test(v)+spf.nzmesh\*test(w))\*spf.inl2.Pinlfdf | 4 | Spatial | Boundary 21 |
| (spf.inl2.Vinlfdf-spf.inl2.Area\*spf.inl2.Uavfdf)\*test(spf.inl2.Pinlfdf) | 4 |  | Global |

#### Constraints

| **Constraint** | **Constraint force** | **Shape function** | **Selection** | **Details** |
| --- | --- | --- | --- | --- |
| -u+spf.ubndx | test(-u) | Lagrange (Quadratic) | Edges 47–49, 400 | Elemental |
| -v+spf.ubndy | test(-v) | Lagrange (Quadratic) | Edges 47–49, 400 | Elemental |
| -w+spf.ubndz | test(-w) | Lagrange (Quadratic) | Edges 47–49, 400 | Elemental |

* + 1. Outlet 1



Outlet 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Geometry geom1: Dimension 2: Boundary 164 |

Equations





#### Boundary Condition

Settings

| **Description** | **Value** |
| --- | --- |
| Boundary condition | Pressure |

#### Pressure Conditions

Settings

| **Description** | **Value** |
| --- | --- |
| Pressure | Static |
| Pressure | 0 |
| Normal flow | Off |
| Suppress backflow | On |

Used products

|  |
| --- |
| COMSOL Multiphysics |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| spf.meshVol | meshvol\_spatial | m² |  | Boundary 164 |
| spf.meshVolInt | down(meshvol\_spatial) | m³ | Volume of interior mesh element | Boundary 164 |
| spf.c\_here | 384/spf.epsilon\_p | Pa·s/m | Intermediate variable | Boundary 164 |
| spf.rhoFace | down(spf.rho) | kg/m³ | Density face value | Boundary 164 |
| spf.umxTnFace | spf.upwind\_helpx\*spf.nxmesh+spf.upwind\_helpy\*spf.nymesh+spf.upwind\_helpz\*spf.nzmesh | m/s | Relative velocity on face | Boundary 164 |
| spf.upwind\_ns | spf.backflowPenaltyConv\*spf.uNormal | W/m² | Upwind term | Boundary 164 |
| spf.p0 | 0 | Pa | Pressure | Boundary 164 |
| spf.out1.Uav | 0 | m/s | Average velocity | Global |
| spf.out1.p0avfdf | 0 | Pa | Average pressure | Global |
| spf.out1.dz | spf.dz | m | Channel thickness | Boundary 164 |
| spf.out1.Mflow | spf.out1.massFlowRate | kg/s | Mass flow | Global |
| spf.f0 | spf.p0+spf.uNormal\*(spf.backflowPenaltyDiff-spf.backflowPenaltyConv)\*(spf.uNormal<0) | N/m² | Normal stress | Boundary 164 |
| spf.uNormal | u\*nojac(spf.nxmesh)+v\*nojac(spf.nymesh)+w\*nojac(spf.nzmesh) | m/s | Normal velocity | Boundary 164 |
| spf.backflowPenaltyDiff | spf.c\_here\*min((down(spf.mu)+spf.muT)\*spf.meshVol/spf.meshVolInt,down(spf.rho)\*abs(spf.uNormal)/down(spf.epsilon\_p)) | kg²/(m⁴·s²) | Backflow penalty parameter, diffusive contribution | Boundary 164 |
| spf.backflowPenaltyConv | spf.rhoFace\*spf.umxTnFace/spf.epsilon\_p^2 | kg/(m²·s) | Backflow penalty parameter, convective contribution | Boundary 164 |
| spf.out1.volumeFlowRate | spf.out1.intop(u\*spf.nxmesh+v\*spf.nymesh+w\*spf.nzmesh) | m³/s | Outward volume flow rate across feature selection | Global |
| spf.out1.massFlowRate | spf.out1.intop(spf.rho\*(u\*spf.nxmesh+v\*spf.nymesh+w\*spf.nzmesh)) | kg/s | Outward mass flow rate across feature selection | Global |
| spf.out1.pAverage | spf.out1.aveop(p) | Pa | Pressure average over feature selection | Global |

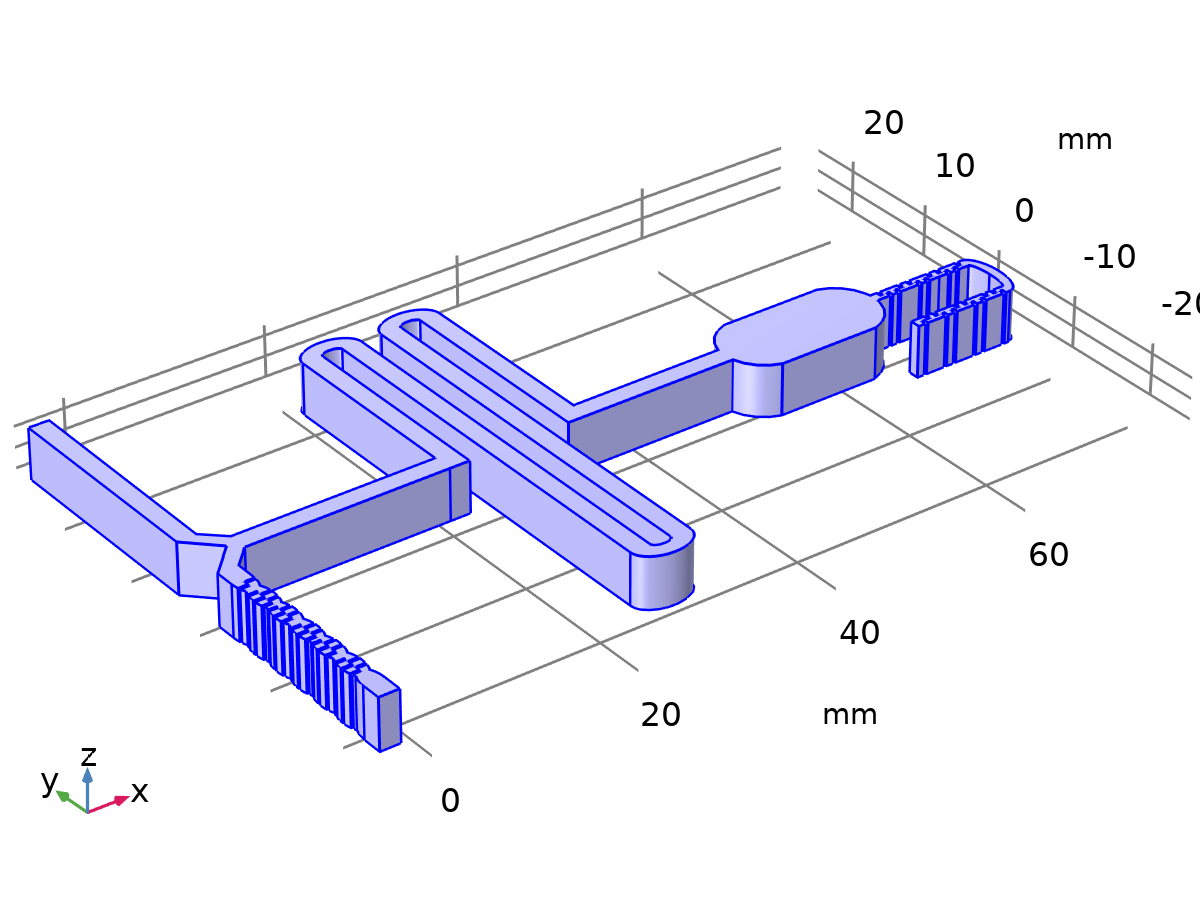
#### Weak Expressions

| **Weak expression** | **Integration order** | **Integration frame** | **Selection** |
| --- | --- | --- | --- |
| -spf.f0\*(test(u)\*spf.nxmesh+test(v)\*spf.nymesh+test(w)\*spf.nzmesh) | 4 | Spatial | Boundary 164 |

* 1. Transport of Diluted Species

Used products

|  |
| --- |
| COMSOL Multiphysics |



Transport of Diluted Species

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1: Dimension 3: All domains |

Equations





* + 1. Interface Settings

#### Discretization

Settings

| **Description** | **Value** |
| --- | --- |
| Concentration | Quadratic |

#### Transport Mechanisms

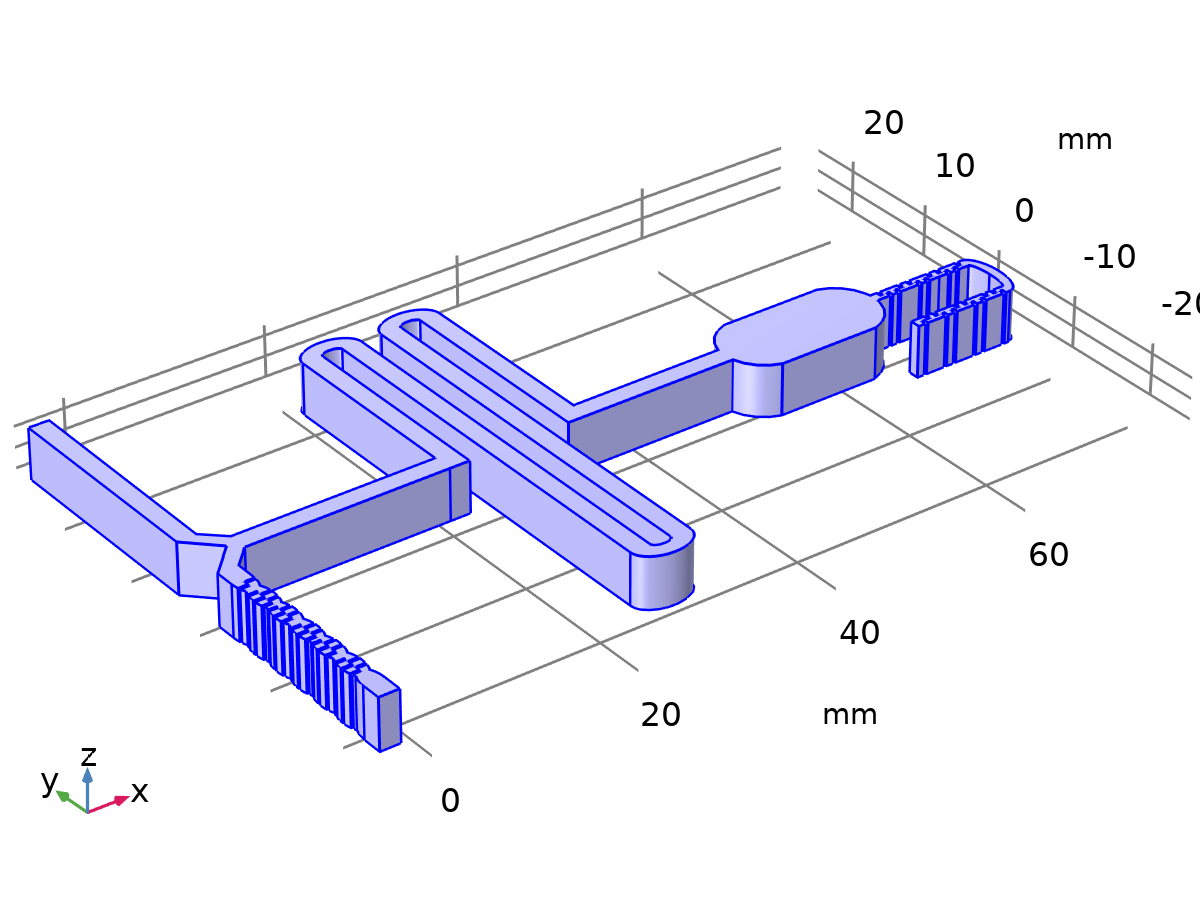
Settings

| **Description** | **Value** |
| --- | --- |
| Convection | On |
| Migration in electric field | Off |
| Mass transfer in porous media | Off |

* + 1. Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** | **Details** |
| --- | --- | --- | --- | --- | --- |
| tds.R\_c | 0 | mol/(m³·s) | Total rate expression | Domain 1 | + operation |
| tds.cP\_c | 0 | mol/kg | Concentration species absorbed to the solid | Domain 1 | + operation |
| tds.cP\_c | 0 | mol/kg | Concentration species absorbed to the solid | Boundaries 1–269 | + operation |
| tds.KP\_c | 0 | m³/kg | Adsorption isotherm, first concentration derivative | Domain 1 | + operation |
| tds.KP\_c | 0 | m³/kg | Adsorption isotherm, first concentration derivative | Boundaries 1–269 | + operation |
| tds.poro | 1 | 1 | Porosity | Domain 1 |  |
| tds.theta\_g | 0 | 1 | Gas volume fraction | Domain 1 |  |
| tds.theta | tds.poro | 1 | Mobile fluid volume fraction | Domain 1 |  |
| tds.nx | dnx | 1 | Normal vector, x component | Boundaries 1–269 |  |
| tds.ny | dny | 1 | Normal vector, y component | Boundaries 1–269 |  |
| tds.nz | dnz | 1 | Normal vector, z component | Boundaries 1–269 |  |
| tds.nxmesh | dnxmesh | 1 | Normal vector (mesh), x component | Boundaries 1–269 |  |
| tds.nymesh | dnymesh | 1 | Normal vector (mesh), y component | Boundaries 1–269 |  |
| tds.nzmesh | dnzmesh | 1 | Normal vector (mesh), z component | Boundaries 1–269 |  |
| tds.nxc | root.nxc/tds.ncLen | 1 | Normal vector, x component | Boundaries 1–269 |  |
| tds.nyc | root.nyc/tds.ncLen | 1 | Normal vector, y component | Boundaries 1–269 |  |
| tds.nzc | root.nzc/tds.ncLen | 1 | Normal vector, z component | Boundaries 1–269 |  |
| tds.ncLen | sqrt(root.nxc^2+root.nyc^2+root.nzc^2+eps) | 1 | Help variable | Boundaries 1–269 |  |
| tds.cbf\_c | 0 | mol/(m²·s) | Convective boundary flux | Boundaries 1–269 |  |
| tds.u | 0 | m/s | Velocity field, x component | Domain 1 |  |
| tds.v | 0 | m/s | Velocity field, y component | Domain 1 |  |
| tds.w | 0 | m/s | Velocity field, z component | Domain 1 |  |

* + 1. Transport Properties 1



Transport Properties 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1: Dimension 3: All domains |

Equations





#### Convection

Settings

| **Description** | **Value** |
| --- | --- |
| Velocity field | Velocity field (spf) |

#### Diffusion

Settings

| **Description** | **Value** |
| --- | --- |
| Source | Material |
| Material | None |
| Diffusion coefficient | User defined |
| Diffusion coefficient | {{D, 0, 0}, {0, D, 0}, {0, 0, D}} |

#### Coordinate System Selection

Settings

| **Description** | **Value** |
| --- | --- |
| Coordinate system | Global coordinate system |

#### Model Input

Settings

| **Description** | **Value** |
| --- | --- |
| Temperature | Common model input |

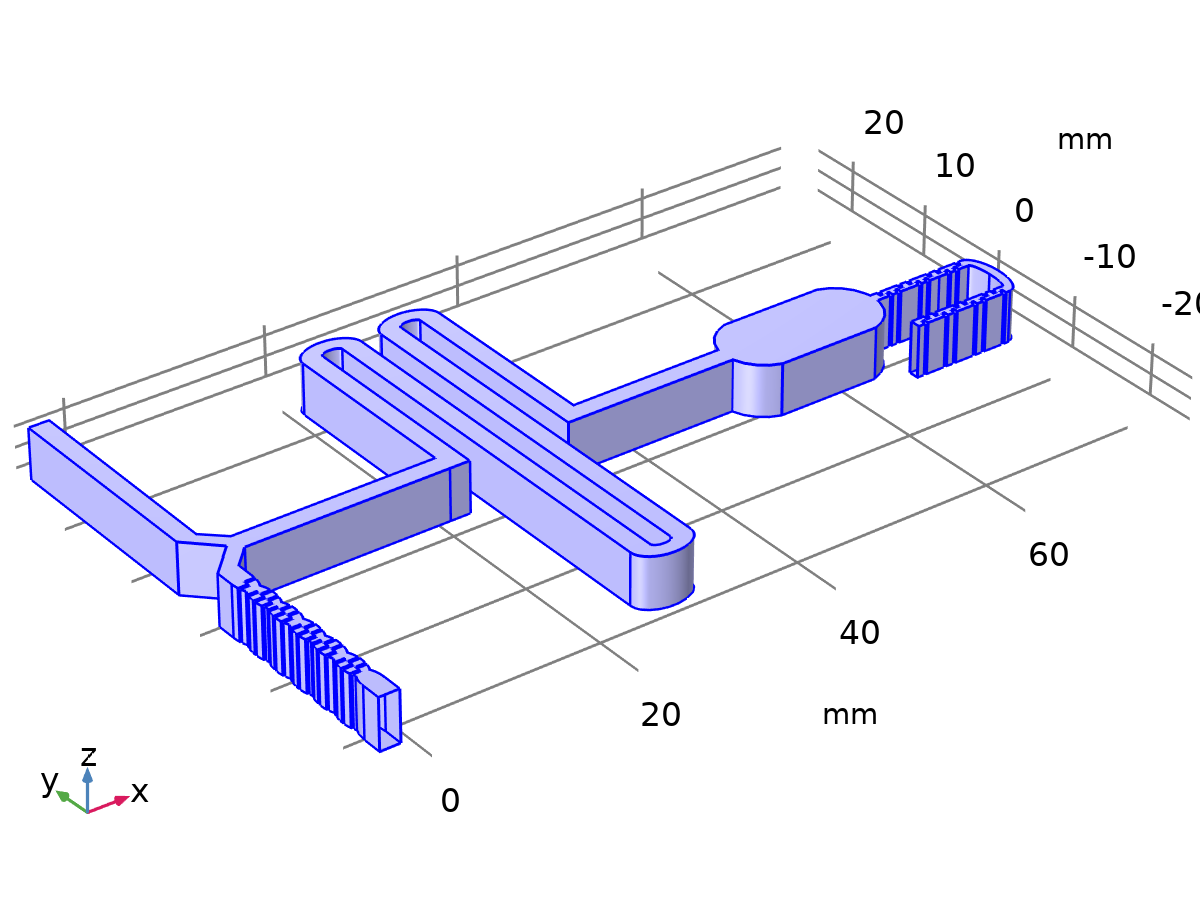
#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** | **Details** |
| --- | --- | --- | --- | --- | --- |
| domflux.cx | tds.dflux\_cx | mol/(m²·s) | Domain flux, x component | Domain 1 |  |
| domflux.cy | tds.dflux\_cy | mol/(m²·s) | Domain flux, y component | Domain 1 |  |
| domflux.cz | tds.dflux\_cz | mol/(m²·s) | Domain flux, z component | Domain 1 |  |
| tds.ndflux\_c | tds.bndFlux\_c | mol/(m²·s) | Normal diffusive flux | Boundaries 1–269 |  |
| tds.ncflux\_c | tds.cflux\_cx\*tds.nxc+tds.cflux\_cy\*tds.nyc+tds.cflux\_cz\*tds.nzc | mol/(m²·s) | Normal convective flux | Boundaries 1–269 |  |
| tds.ntflux\_c | tds.bndFlux\_c+tds.cflux\_cx\*tds.nxc+tds.cflux\_cy\*tds.nyc+tds.cflux\_cz\*tds.nzc | mol/(m²·s) | Normal total flux | Boundaries 1–269 |  |
| tds.u | model.input.u1 | m/s | Velocity field, x component | Domain 1 | Meta |
| tds.v | model.input.u2 | m/s | Velocity field, y component | Domain 1 | Meta |
| tds.w | model.input.u3 | m/s | Velocity field, z component | Domain 1 | Meta |
| tds.bndFlux\_c | -dflux\_spatial(c) | mol/(m²·s) | Boundary flux | Boundaries 1–269 |  |
| tds.D\_cxx | D | m²/s | Diffusion coefficient, xx component | Domain 1 |  |
| tds.D\_cyx | 0 | m²/s | Diffusion coefficient, yx component | Domain 1 |  |
| tds.D\_czx | 0 | m²/s | Diffusion coefficient, zx component | Domain 1 |  |
| tds.D\_cxy | 0 | m²/s | Diffusion coefficient, xy component | Domain 1 |  |
| tds.D\_cyy | D | m²/s | Diffusion coefficient, yy component | Domain 1 |  |
| tds.D\_czy | 0 | m²/s | Diffusion coefficient, zy component | Domain 1 |  |
| tds.D\_cxz | 0 | m²/s | Diffusion coefficient, xz component | Domain 1 |  |
| tds.D\_cyz | 0 | m²/s | Diffusion coefficient, yz component | Domain 1 |  |
| tds.D\_czz | D | m²/s | Diffusion coefficient, zz component | Domain 1 |  |
| tds.Dav\_c | (tds.D\_cxx+tds.D\_cyy+tds.D\_czz)/3 | m²/s | Average diffusion coefficient | Domain 1 |  |
| tds.tflux\_cx | tds.dflux\_cx+tds.cflux\_cx | mol/(m²·s) | Total flux, x component | Domain 1 | + operation |
| tds.tflux\_cy | tds.dflux\_cy+tds.cflux\_cy | mol/(m²·s) | Total flux, y component | Domain 1 | + operation |
| tds.tflux\_cz | tds.dflux\_cz+tds.cflux\_cz | mol/(m²·s) | Total flux, z component | Domain 1 | + operation |
| tds.dfluxMag\_c | sqrt(tds.dflux\_cx^2+tds.dflux\_cy^2+tds.dflux\_cz^2) | mol/(m²·s) | Diffusive flux magnitude | Domain 1 |  |
| tds.tfluxMag\_c | sqrt(tds.tflux\_cx^2+tds.tflux\_cy^2+tds.tflux\_cz^2) | mol/(m²·s) | Total flux magnitude | Domain 1 |  |
| tds.dpflux\_cx | 0 | mol/(m²·s) | Dispersive flux, x component | Domain 1 |  |
| tds.dpflux\_cy | 0 | mol/(m²·s) | Dispersive flux, y component | Domain 1 |  |
| tds.dpflux\_cz | 0 | mol/(m²·s) | Dispersive flux, z component | Domain 1 |  |
| tds.dflux\_cx | -tds.D\_cxx\*cx-tds.D\_cxy\*cy-tds.D\_cxz\*cz | mol/(m²·s) | Diffusive flux, x component | Domain 1 |  |
| tds.dflux\_cy | -tds.D\_cyx\*cx-tds.D\_cyy\*cy-tds.D\_cyz\*cz | mol/(m²·s) | Diffusive flux, y component | Domain 1 |  |
| tds.dflux\_cz | -tds.D\_czx\*cx-tds.D\_czy\*cy-tds.D\_czz\*cz | mol/(m²·s) | Diffusive flux, z component | Domain 1 |  |
| tds.grad\_cx | cx | mol/m⁴ | Concentration gradient, x component | Domain 1 |  |
| tds.grad\_cy | cy | mol/m⁴ | Concentration gradient, y component | Domain 1 |  |
| tds.grad\_cz | cz | mol/m⁴ | Concentration gradient, z component | Domain 1 |  |
| tds.cflux\_cx | c\*tds.u | mol/(m²·s) | Convective flux, x component | Domain 1 |  |
| tds.cflux\_cy | c\*tds.v | mol/(m²·s) | Convective flux, y component | Domain 1 |  |
| tds.cflux\_cz | c\*tds.w | mol/(m²·s) | Convective flux, z component | Domain 1 |  |
| tds.cfluxMag\_c | sqrt(tds.cflux\_cx^2+tds.cflux\_cy^2+tds.cflux\_cz^2) | mol/(m²·s) | Convective flux magnitude | Domain 1 |  |
| tds.Res\_c | -tds.D\_cxx\*cxx-tds.D\_cxy\*cxy-tds.D\_cxz\*cxz-tds.D\_cyx\*cyx-tds.D\_cyy\*cyy-tds.D\_cyz\*cyz-tds.D\_czx\*czx-tds.D\_czy\*czy-tds.D\_czz\*czz+tds.u\*cx+tds.v\*cy+tds.w\*cz-tds.R\_c | mol/(m³·s) | Equation residual | Domain 1 |  |

#### Shape functions

| **Name** | **Shape function** | **Unit** | **Description** | **Shape frame** | **Selection** |
| --- | --- | --- | --- | --- | --- |
| c | Lagrange (Quadratic) | mol/m³ | Concentration | Spatial | Domain 1 |

* + 1. No Flux 1



No Flux 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Geometry geom1: Dimension 2: All boundaries |

Equations

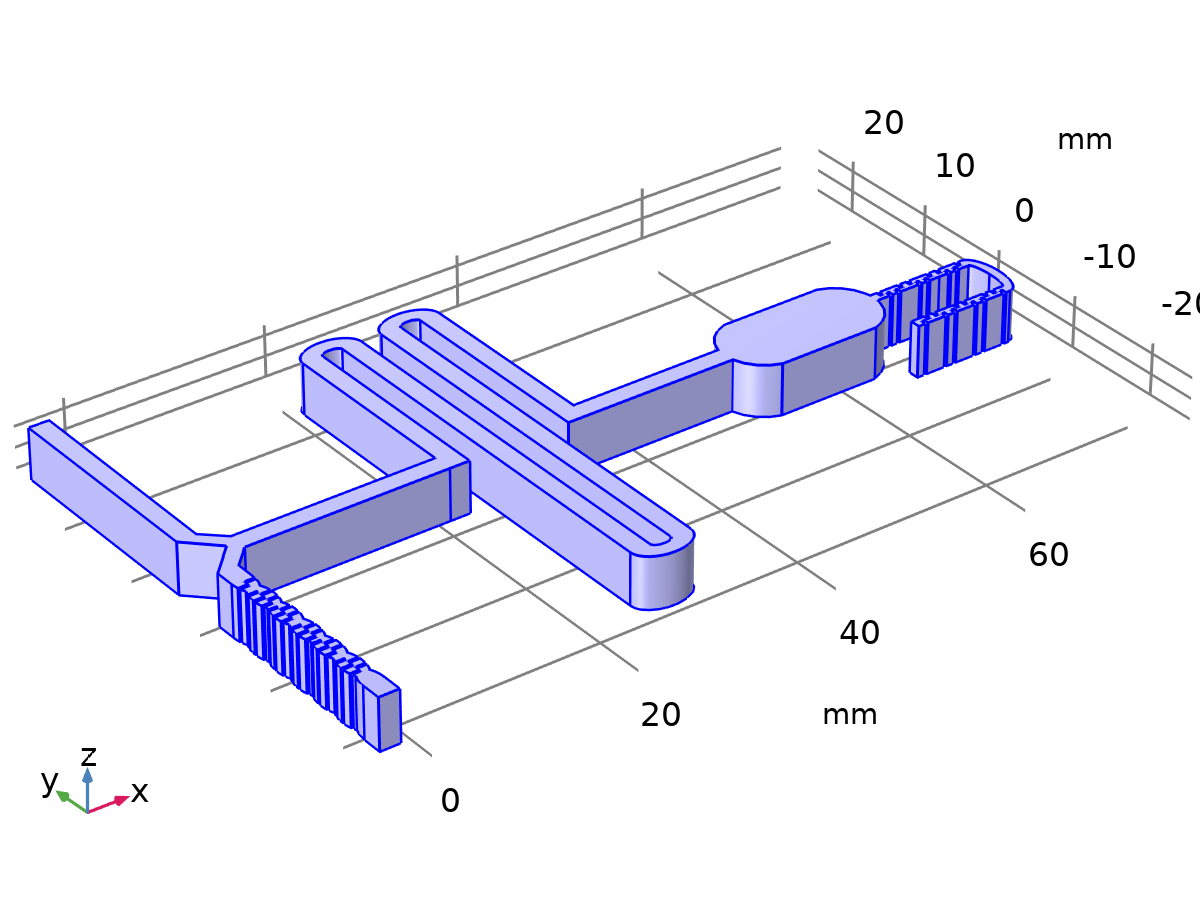


#### Convection

Settings

| **Description** | **Value** |
| --- | --- |
| Include | Off |

* + 1. Initial Values 1



Initial Values 1

Selection

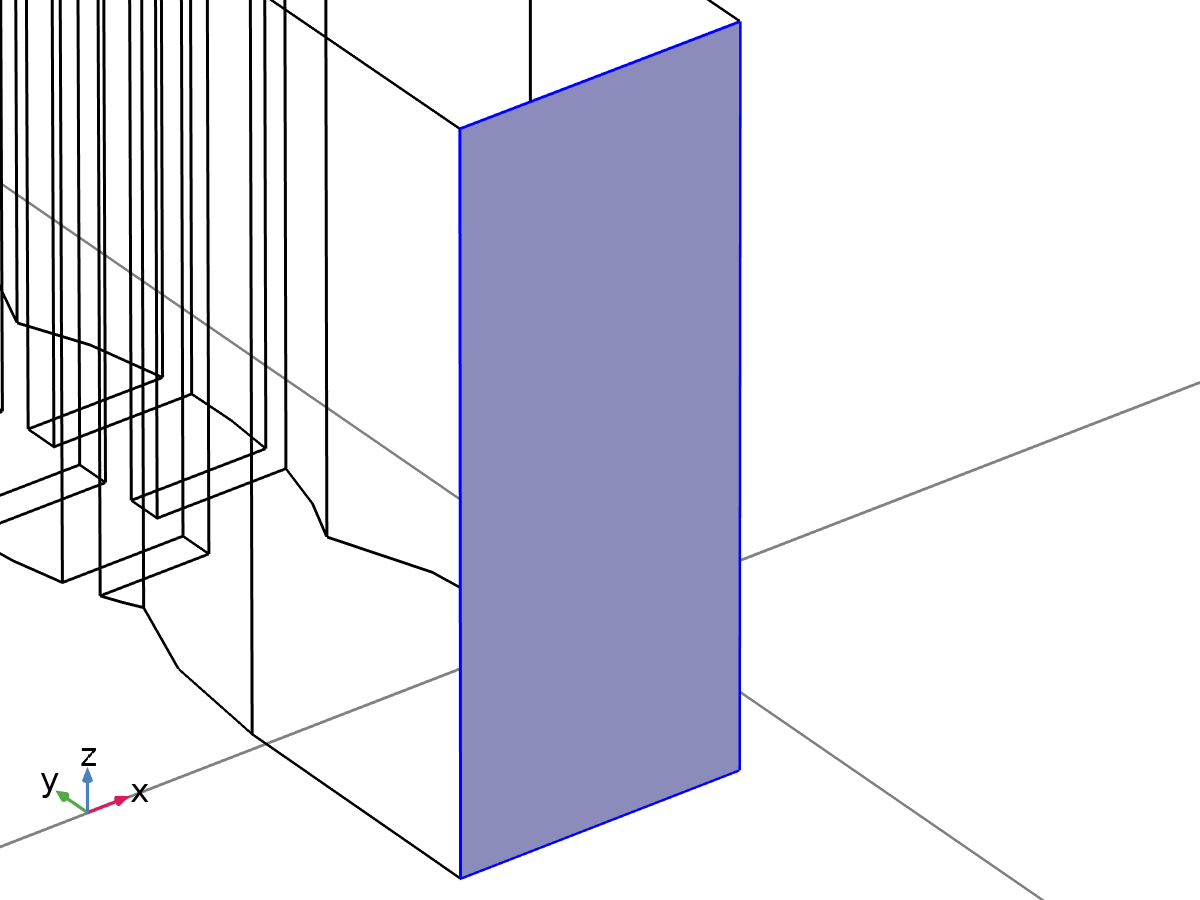
|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1: Dimension 3: All domains |

#### Initial Values

Settings

| **Description** | **Value** |
| --- | --- |
| Concentration | 0 |

* + 1. Concentration 1



Concentration 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Geometry geom1: Dimension 2: Boundary 2 |

Equations



#### Concentration

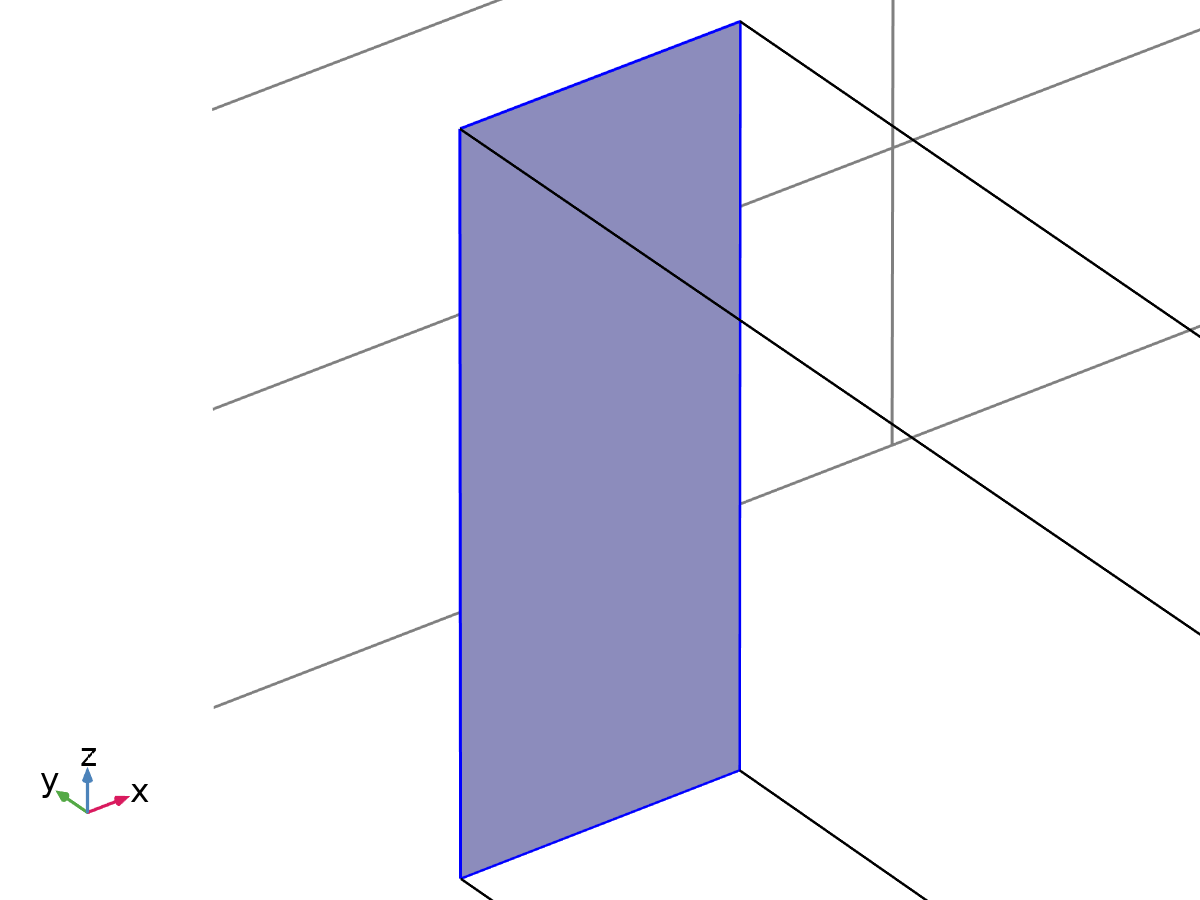
Settings

| **Description** | **Value** |
| --- | --- |
| Species c | On |
| Concentration | cL |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| tds.c0\_c | cL | mol/m³ | Concentration | Boundary 2 |

* + 1. Concentration 2



Concentration 2

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Geometry geom1: Dimension 2: Boundary 21 |

Equations



#### Concentration

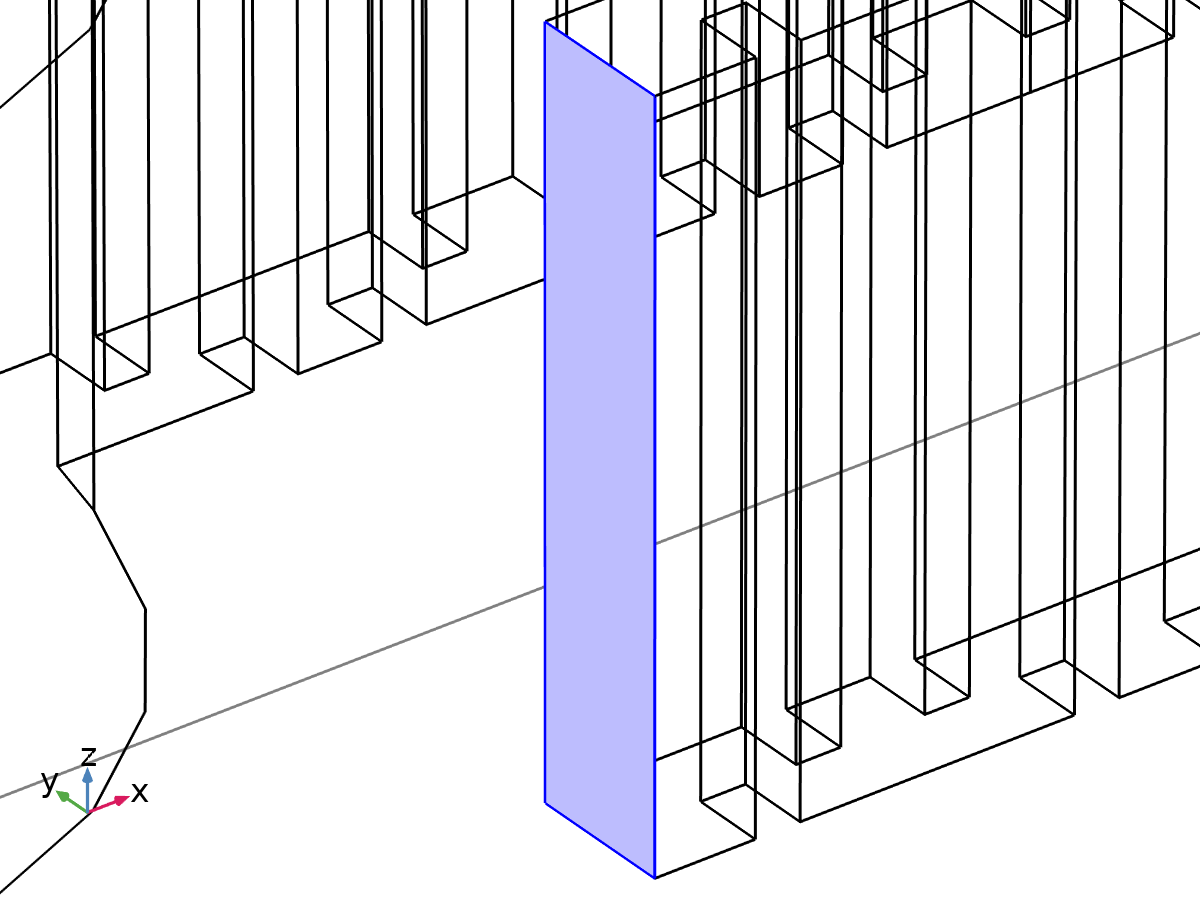
Settings

| **Description** | **Value** |
| --- | --- |
| Species c | On |
| Concentration | cR |

#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| tds.c0\_c | cR | mol/m³ | Concentration | Boundary 21 |

* + 1. Outflow 1



Outflow 1

Selection

|  |  |
| --- | --- |
| Geometric entity level | Boundary |
| Selection | Geometry geom1: Dimension 2: Boundary 164 |

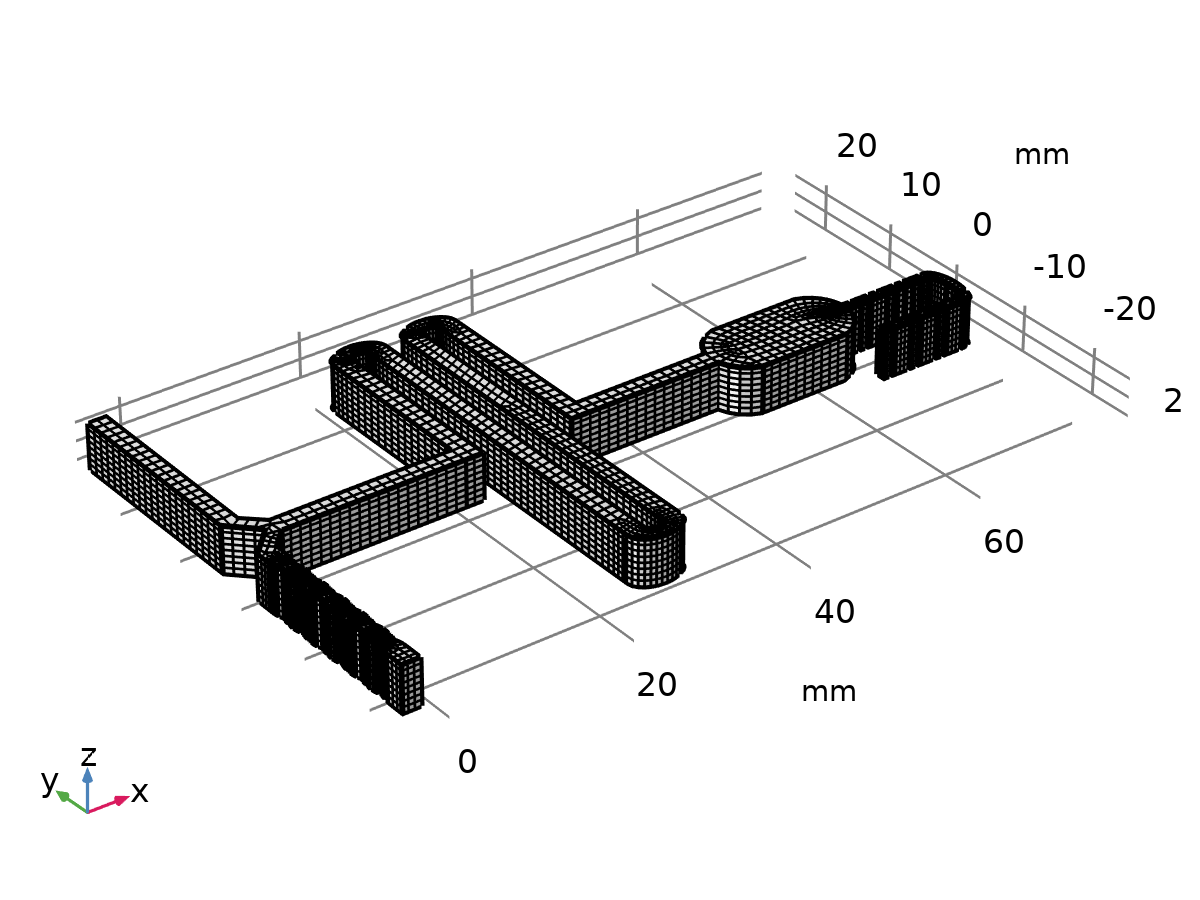
Equations



#### Variables

| **Name** | **Expression** | **Unit** | **Description** | **Selection** |
| --- | --- | --- | --- | --- |
| tds.out1.c0\_avg\_c | tds.out1.int(c\*(tds.u\*tds.nx+tds.v\*tds.ny+tds.w\*tds.nz))/tds.out1.int(tds.u\*tds.nx+tds.v\*tds.ny+tds.w\*tds.nz) | mol/m³ | Concentration | Global |

* 1. Mesh 1



Mesh 1

Mesh statistics

| **Description** | **Value** |
| --- | --- |
| Minimum element quality | 0.02018 |
| Average element quality | 0.6627 |
| Prism | 96 |
| Hexahedron | 9592 |
| Triangle | 24 |
| Quad | 9886 |
| Edge element | 4008 |
| Vertex element | 534 |

* + 1. Size (size)

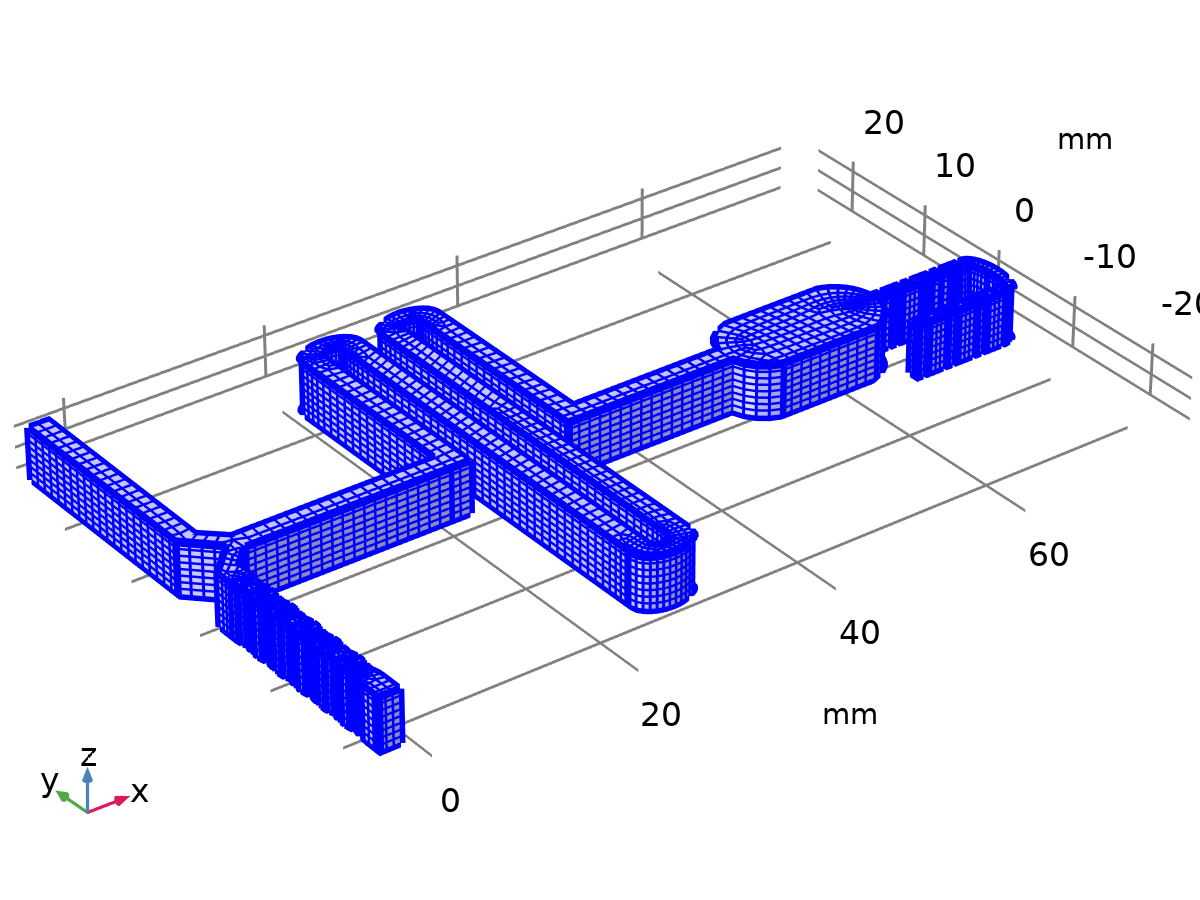
Settings

| **Description** | **Value** |
| --- | --- |
| Calibrate for | Fluid dynamics |
| Maximum element size | 1.07 |
| Minimum element size | 0.319 |
| Curvature factor | 0.6 |
| Resolution of narrow regions | 0.7 |
| Maximum element growth rate | 1.15 |

* + 1. Swept 1 (swe1)

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Remaining |

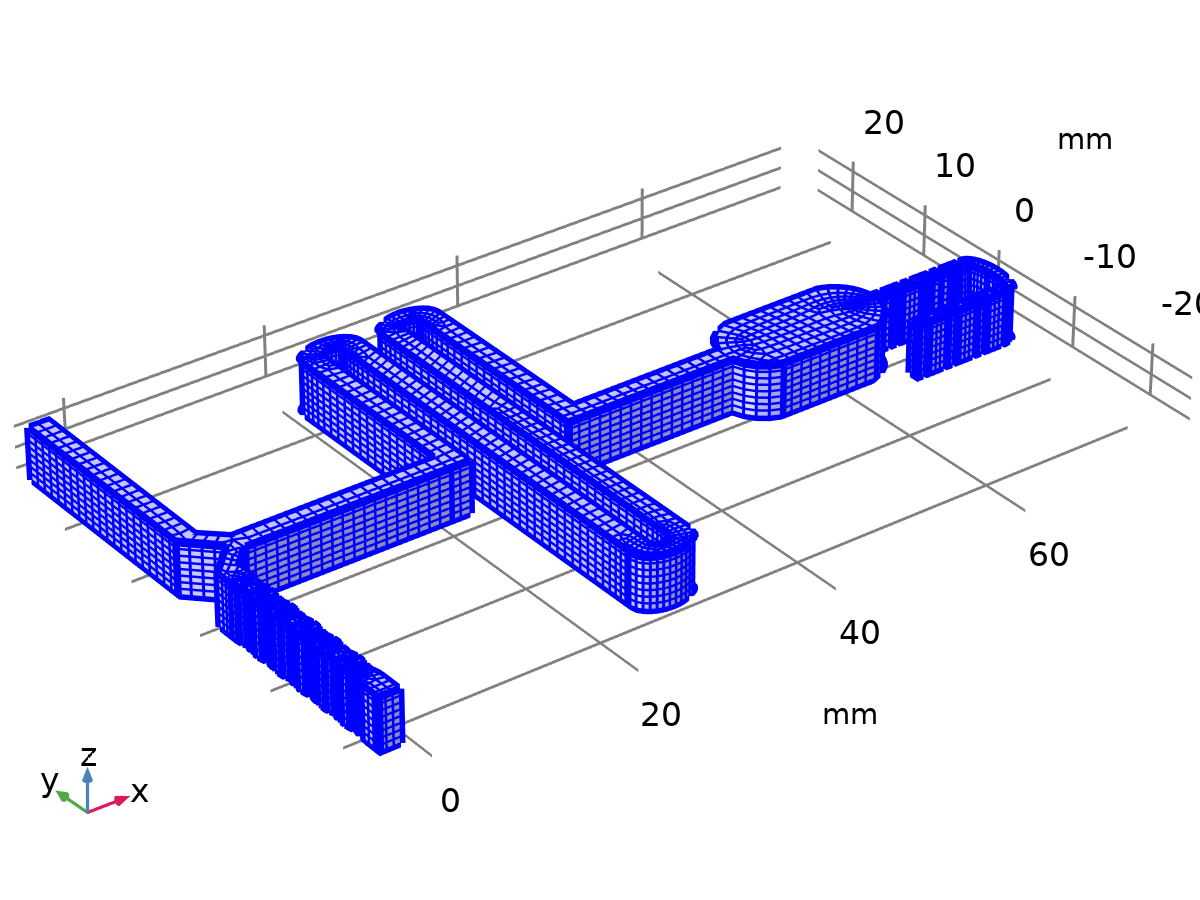


Swept 1

#### Distribution 1 (dis1)

Selection

|  |  |
| --- | --- |
| Geometric entity level | Domain |
| Selection | Geometry geom1: Dimension 3: All domains |



Distribution 1

Settings

| **Description** | **Value** |
| --- | --- |
| Number of elements | 8 |

1. Study 1

Computation information

|  |  |
| --- | --- |
| Computation time | 3 h 14 min 17 s |

* 1. Stationary

Study settings

| **Description** | **Value** |
| --- | --- |
| Include geometric nonlinearity | Off |

Physics and variables selection

| **Physics interface** | **Discretization** |
| --- | --- |
| Laminar Flow (spf) | physics |

Mesh selection

| **Geometry** | **Mesh** |
| --- | --- |
| Geometry 1 (geom1) | mesh1 |

* 1. Stationary 2

Study settings

| **Description** | **Value** |
| --- | --- |
| Include geometric nonlinearity | Off |

Values of dependent variables

| **Description** | **Value** |
| --- | --- |
| Settings | User controlled |
| Method | Solution |
| Study | [Study 1](#cs9031602) |

Study extensions

| **Description** | **Value** |
| --- | --- |
| Auxiliary sweep | On |
| Sweep type | Specified combinations |

Parameters

| **Parameter name** | **Parameter value list** | **Parameter unit** |
| --- | --- | --- |
| D (Diffusion Constant) | 1e-10 5e-11 1e-11 | m^2/s |

Physics and variables selection

| **Physics interface** | **Discretization** |
| --- | --- |
| Transport of Diluted Species (tds) | physics |

Mesh selection

| **Geometry** | **Mesh** |
| --- | --- |
| Geometry 1 (geom1) | mesh1 |

* + 1. Study extensions

Study extensions

| **Description** | **Value** |
| --- | --- |
| Auxiliary sweep | On |
| Sweep type | Specified combinations |

Parameters

| **Parameter name** | **Parameter value list** | **Parameter unit** |
| --- | --- | --- |
| D (Diffusion Constant) | 1e-10 5e-11 1e-11 | m^2/s |

* 1. Time Dependent

| **Times** | **Unit** |
| --- | --- |
| range(0,0.2,3) | s |

Study settings

| **Description** | **Value** |
| --- | --- |
| Include geometric nonlinearity | Off |

Study settings

| **Description** | **Value** |
| --- | --- |
| Output times | {0, 0.2, 0.4, 0.6000000000000001, 0.8, 1, 1.2000000000000002, 1.4000000000000001, 1.6, 1.8, 2, 2.2, 2.4000000000000004, 2.6, 2.8000000000000003, 3} |

Physics and variables selection

| **Physics interface** | **Discretization** |
| --- | --- |
| Laminar Flow (spf) | physics |
| Transport of Diluted Species (tds) | physics |

Mesh selection

| **Geometry** | **Mesh** |
| --- | --- |
| Geometry 1 (geom1) | mesh1 |

* 1. Solver Configurations
     1. Solution 1

#### Compile Equations: Stationary (st1)

Study and step

| **Description** | **Value** |
| --- | --- |
| Use study | [Study 1](#cs9031602) |
| Use study step | [Stationary](#cs1523593) |

Log

<---- Compile Equations: Stationary in Study 1/Solution 1 (sol1) ---------------

Started at Dec 1, 2021 1:27:09 AM.

Geometry shape function: Linear Lagrange

Running on Intel64 Family 6 Model 142 Stepping 12, GenuineIntel.

Using 1 socket with 4 cores in total on LAPTOP-QEU20CEA.

Available memory: 8.08 GB.

Time: 2 s.

Physical memory: 1.28 GB

Virtual memory: 1.93 GB

Ended at Dec 1, 2021 1:27:11 AM.

----- Compile Equations: Stationary in Study 1/Solution 1 (sol1) -------------->

#### Dependent Variables 1 (v1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | [Stationary](#cs1523593) |

Initial value calculation constants

| **Constant name** | **Initial value source** |
| --- | --- |
| timestep | 0.003[s] |

Log

<---- Dependent Variables 1 in Study 1/Solution 1 (sol1) -----------------------

Started at Dec 1, 2021 1:27:11 AM.

Solution time: 0 s.

Physical memory: 1.3 GB

Virtual memory: 1.95 GB

Ended at Dec 1, 2021 1:27:12 AM.

----- Dependent Variables 1 in Study 1/Solution 1 (sol1) ---------------------->

##### Concentration (comp1.c) (comp1\_c)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.c |
| Internal variables | {comp1.uflux.c, comp1.dflux.c} |
| Solve for this field | Off |

##### Pressure (comp1.p) (comp1\_p)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p |

##### Velocity field (comp1.u) (comp1\_u)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u, comp1.v, comp1.w} |
| Internal variables | comp1.spf.isFluidHasBeenSolved |

##### Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf) (comp1\_spf\_inl1\_Pinlfdf)

General

| **Description** | **Value** |
| --- | --- |
| State components | comp1.spf.inl1.Pinlfdf |

##### Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf) (comp1\_spf\_inl2\_Pinlfdf)

General

| **Description** | **Value** |
| --- | --- |
| State components | comp1.spf.inl2.Pinlfdf |

#### Stationary Solver 1 (s1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | [Stationary](#cs1523593) |

Log

<---- Stationary Solver 1 in Study 1/Solution 1 (sol1) -------------------------

Started at Dec 1, 2021 1:27:13 AM.

Nonlinear solver

Number of degrees of freedom solved for: 308675 (plus 1 internal DOFs).

Nonsymmetric matrix found.

Scales for dependent variables:

Pressure (comp1.p): 0.11

Velocity field (comp1.u): 0.11

Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf): 1

Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf): 0.71

Orthonormal null-space function used.

Iter      SolEst      ResEst     Damping    Stepsize #Res #Jac #Sol LinIt   LinErr   LinRes

   1          85     7.9e+05   0.0100000          86    2    1    2     6    0.093       24

   2         7.1     5.3e+03   0.1000000         7.9    3    2    5    21   0.0031      8.2

   3       0.051     4.8e+04   1.0000000        0.77    4    3    8    47    0.076      0.3

   4      0.0087       6e+03   1.0000000       0.049    5    4   11    53    0.005        -

   5      0.0033     5.7e+03   1.0000000       0.016    7    5   14    62   0.0013        -

   6       0.023     5.8e+03   0.1000000       0.025    8    6   17    71   0.0084        -

   7     0.00043       5e+02   1.0000000       0.022   10    7   20    77   0.0067        -

Solution time: 2049 s. (34 minutes, 9 seconds)

Physical memory: 3.83 GB

Virtual memory: 5.18 GB

Ended at Dec 1, 2021 2:01:22 AM.

----- Stationary Solver 1 in Study 1/Solution 1 (sol1) ------------------------>

##### Advanced (aDef)

Assembly settings

| **Description** | **Value** |
| --- | --- |
| Reuse sparsity pattern | On |

##### Fully Coupled 1 (fc1)

General

| **Description** | **Value** |
| --- | --- |
| Linear solver | [AMG, fluid flow variables (spf)](#cs4425168) |

Method and termination

| **Description** | **Value** |
| --- | --- |
| Initial damping factor | 0.01 |
| Maximum number of iterations | 100 |

##### AMG, fluid flow variables (spf) (i1)

General

| **Description** | **Value** |
| --- | --- |
| Nonlinear-based error norm | On |
| Maximum number of iterations | 1000 |

Error

| **Description** | **Value** |
| --- | --- |
| Factor in error estimate | 20 |

###### Multigrid 1 (mg1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | Smoothed aggregation AMG |
| Maximum number of DOFs at coarsest level | 80000 |
| Strength of connections | 0.02 |
| Construct prolongators componentwise | On |
| Prolongator smoothing | Off |

Presmoother (pr)

Vanka 1 (va1)

Main

| **Description** | **Value** |
| --- | --- |
| Sweep type | SSOR |
| Number of iterations | 0 |
| Variables | {Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf), Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf), Pressure (comp1.p)} |

Secondary

| **Description** | **Value** |
| --- | --- |
| Relaxation factor | 0.5 |

Postsmoother (po)

Vanka 1 (va1)

Main

| **Description** | **Value** |
| --- | --- |
| Sweep type | SSOR |
| Number of iterations | 1 |
| Variables | {Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf), Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf), Pressure (comp1.p)} |

Secondary

| **Description** | **Value** |
| --- | --- |
| Number of secondary iterations | 2 |
| Relaxation factor | 0.5 |

Coarse Solver (cs)

Direct 1 (d1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | PARDISO |
| Pivoting perturbation | 1.0E-13 |

#### Solution Store 1 (su1)

General

| **Description** | **Value** |
| --- | --- |
| Solution | Solution Store 1 |

#### Compile Equations: Stationary 2 (st2)

Study and step

| **Description** | **Value** |
| --- | --- |
| Use study | [Study 1](#cs9031602) |
| Use study step | [Stationary 2](#cs7661806) |

Log

<---- Compile Equations: Stationary 2 in Study 1/Solution 1 (sol1) -------------

Started at Dec 1, 2021 2:01:22 AM.

Geometry shape function: Linear Lagrange

Time: 4 s.

Physical memory: 1.52 GB

Virtual memory: 2.15 GB

Ended at Dec 1, 2021 2:01:26 AM.

----- Compile Equations: Stationary 2 in Study 1/Solution 1 (sol1) ------------>

#### Dependent Variables 2 (v2)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | [Stationary 2](#cs7661806) |

Initial values of variables solved for

| **Description** | **Value** |
| --- | --- |
| Method | Solution |
| Solution | [Solution 1](#cs9250785) |

Values of variables not solved for

| **Description** | **Value** |
| --- | --- |
| Method | Solution |
| Solution | [Solution 1](#cs9250785) |

Initial value calculation constants

| **Constant name** | **Initial value source** |
| --- | --- |
| D | 1e-10[m^2/s] 5e-11[m^2/s] 1e-11[m^2/s] |
| timestep | 0.003[s] |

Log

<---- Dependent Variables 2 in Study 1/Solution 1 (sol1) -----------------------

Started at Dec 1, 2021 2:01:28 AM.

Initial values of variables solved for: Solution 1 (sol1).

Values of variables not solved for: Solution 1 (sol1).

Solution time: 0 s.

Physical memory: 1.55 GB

Virtual memory: 2.15 GB

Ended at Dec 1, 2021 2:01:28 AM.

----- Dependent Variables 2 in Study 1/Solution 1 (sol1) ---------------------->

##### Concentration (comp1.c) (comp1\_c)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.c |
| Internal variables | {comp1.uflux.c, comp1.dflux.c, comp1.tds.dt2Inv\_c} |

##### Pressure (comp1.p) (comp1\_p)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p |
| Solve for this field | Off |

##### Velocity field (comp1.u) (comp1\_u)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u, comp1.v, comp1.w} |
| Internal variables | {comp1.spf.isFluidHasBeenSolved, comp1.spf.dt2Inv\_u} |
| Solve for this field | Off |

##### Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf) (comp1\_spf\_inl1\_Pinlfdf)

General

| **Description** | **Value** |
| --- | --- |
| State components | comp1.spf.inl1.Pinlfdf |
| Solve for this state | Off |

##### Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf) (comp1\_spf\_inl2\_Pinlfdf)

General

| **Description** | **Value** |
| --- | --- |
| State components | comp1.spf.inl2.Pinlfdf |
| Solve for this state | Off |

#### Stationary Solver 2 (s2)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | [Stationary 2](#cs7661806) |

Results while solving

| **Description** | **Value** |
| --- | --- |
| Probes | None |

Log

<---- Stationary Solver 2 in Study 1/Solution 1 (sol1) -------------------------

Started at Dec 1, 2021 2:01:29 AM.

Continuation solver

Nonlinear solver

Number of degrees of freedom solved for: 97869 (plus 47877 internal DOFs).

Continuation parameter D = 1e-10.

Nonsymmetric matrix found.

Scales for dependent variables:

Concentration (comp1.c): 1

Orthonormal null-space function used.

Iter      SolEst      ResEst     Damping    Stepsize #Res #Jac #Sol LinIt   LinErr   LinRes

   1          58     3.8e+02   0.0100000          58    2    1    2   200      2.6   0.0033

   2          21     9.8e+03   0.0313351          21    3    2    4   229     0.12  0.00024

   3           2     2.9e+04   0.3133508         2.8    4    3    6   259     0.11  0.00023

   4        0.11     5.2e+04   1.0000000        0.66    5    4    9   336     0.12   0.0012

   5       0.077     4.5e+04   1.0000000       0.064    6    5   12   390     0.12        -

   6       0.063     4.3e+04   0.3431282       0.058    8    6   16   425     0.11        -

   7       0.059     4.2e+04   0.3404948       0.054   10    7   20   454      0.1        -

   8       0.056     4.1e+04   0.3391104       0.052   12    8   24   481     0.12        -

   9       0.055     4.1e+04   0.3374030        0.05   14    9   28   507     0.12        -

  10       0.053       4e+04   0.3350904       0.049   16   10   32   532     0.12        -

  11       0.051       4e+04   0.3326843       0.047   18   11   36   557     0.11        -

  12        0.05     3.9e+04   0.3313443       0.045   20   12   40   582      0.1        -

  13       0.048     3.9e+04   0.3311122       0.044   22   13   44   607    0.093        -

  14       0.047     3.9e+04   0.3329709       0.043   24   14   48   630     0.12        -

  15       0.046     3.8e+04   0.3329855       0.042   26   15   52   653     0.11        -

  16       0.046     3.8e+04   0.3332086       0.042   28   16   56   676      0.1        -

  17       0.045     3.7e+04   0.3334980       0.041   30   17   60   698     0.12        -

  18       0.044     3.7e+04   0.3335643       0.041   32   18   64   720     0.11        -

  19       0.044     3.6e+04   0.3339869        0.04   34   19   68   742      0.1        -

  20       0.043     3.6e+04   0.3380158        0.04   36   20   72   761     0.12        -

  21       0.042     3.6e+04   0.3400585       0.039   38   21   76   780     0.11        -

  22       0.041     3.5e+04   0.3407578       0.038   40   22   80   799     0.11        -

  23        0.04     3.5e+04   0.3419232       0.037   42   23   84   818    0.099        -

  24       0.039     3.5e+04   0.3429752       0.036   44   24   88   837    0.094        -

  25       0.038     3.5e+04   0.3436387       0.035   46   25   92   854     0.12        -

  26       0.037     3.4e+04   0.3447814       0.035   48   26   96   872     0.12        -

  27       0.036     3.4e+04   0.3490802       0.034   50   27  100   889     0.12        -

  28       0.036     3.4e+04   0.3504959       0.033   52   28  104   907    0.091        -

  29       0.034     3.4e+04   0.3539232       0.032   54   29  108   922    0.091        -

  30       0.033     3.4e+04   0.3573826       0.031   56   30  112   937    0.089        -

  31       0.032     3.4e+04   0.3616620        0.03   58   31  116   951    0.085        -

  32       0.031     3.4e+04   0.3643985       0.028   60   32  120   965     0.08        -

  33        0.03     3.4e+04   1.0000000       0.023   61   33  123   975    0.097        -

  34       0.025     3.3e+04   1.0000000        0.02   62   34  126   986    0.088        -

  35       0.019     3.1e+04   1.0000000       0.018   63   35  129   995    0.083        -

  36       0.013     2.8e+04   1.0000000       0.014   64   36  132  1003    0.085        -

  37      0.0097     2.4e+04   1.0000000       0.011   65   37  135  1011    0.096        -

  38       0.007       2e+04   1.0000000      0.0084   66   38  138  1025    0.081        -

  39      0.0048     1.6e+04   1.0000000      0.0066   67   39  141  1041     0.07        -

  40      0.0029     1.2e+04   1.0000000      0.0045   68   40  144  1057     0.12        -

  41      0.0018     8.6e+03   1.0000000      0.0029   69   41  147  1069    0.083        -

  42      0.0011     6.3e+03   1.0000000       0.002   70   42  150  1082    0.071        -

  43     0.00065     6.1e+03   1.0000000      0.0013   72   43  153  1093    0.068        -

Continuation parameter D = 5e-11.

Iter      SolEst      ResEst     Damping    Stepsize #Res #Jac #Sol LinIt   LinErr   LinRes

   1     0.00091     3.7e+03   1.0000000      0.0011   77   44  157  1348     0.12   0.0013

Continuation parameter D = 1e-11.

Iter      SolEst      ResEst     Damping    Stepsize #Res #Jac #Sol LinIt   LinErr   LinRes

   1     0.00089     4.7e+03   1.0000000     0.00092   82   45  161  1566     0.11   0.0012

Solution time: 802 s. (13 minutes, 22 seconds)

Physical memory: 2.47 GB

Virtual memory: 3.06 GB

Ended at Dec 1, 2021 2:14:50 AM.

----- Stationary Solver 2 in Study 1/Solution 1 (sol1) ------------------------>

##### Advanced (aDef)

Assembly settings

| **Description** | **Value** |
| --- | --- |
| Reuse sparsity pattern | On |

##### Parametric 1 (p1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | [Stationary 2](#cs7661806) |

Parameters

| **Parameter name** | **Parameter value list** | **Parameter unit** |
| --- | --- | --- |
| D | 1e-10 5e-11 1e-11 | m^2/s |

##### Fully Coupled 1 (fc1)

General

| **Description** | **Value** |
| --- | --- |
| Linear solver | [AMG, concentrations (tds)](#cs3257949) |

Method and termination

| **Description** | **Value** |
| --- | --- |
| Initial damping factor | 0.01 |
| Minimum damping factor | 1.0E-6 |
| Maximum number of iterations | 50 |

##### AMG, concentrations (tds) (i1)

General

| **Description** | **Value** |
| --- | --- |
| Nonlinear-based error norm | On |
| Maximum number of iterations | 1000 |

###### Multigrid 1 (mg1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | Smoothed aggregation AMG |
| Maximum number of DOFs at coarsest level | 50000 |
| Construct prolongators componentwise | On |
| Prolongator smoothing | Off |

Presmoother (pr)

SOR Line 1 (sl1)

Main

| **Description** | **Value** |
| --- | --- |
| Sweep type | SSOR |
| Number of iterations | 1 |
| Relaxation factor | 0.7 |

Secondary

| **Description** | **Value** |
| --- | --- |
| Relaxation factor | 0.5 |

Postsmoother (po)

SOR Line 1 (sl1)

Main

| **Description** | **Value** |
| --- | --- |
| Sweep type | SSOR |
| Number of iterations | 1 |
| Relaxation factor | 0.7 |

Secondary

| **Description** | **Value** |
| --- | --- |
| Relaxation factor | 0.5 |

Coarse Solver (cs)

Direct 1 (d1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | PARDISO |
| Pivoting perturbation | 1.0E-13 |

#### Solution Store 2 (su2)

General

| **Description** | **Value** |
| --- | --- |
| Solution | Solution Store 2 |

#### Compile Equations: Time Dependent (st3)

Study and step

| **Description** | **Value** |
| --- | --- |
| Use study | [Study 1](#cs9031602) |
| Use study step | [Time Dependent](#cs6296452) |

Log

<---- Compile Equations: Time Dependent in Study 1/Solution 1 (sol1) -----------

Started at Dec 1, 2021 2:14:50 AM.

Geometry shape function: Linear Lagrange

Time: 4 s.

Physical memory: 1.48 GB

Virtual memory: 2.21 GB

Ended at Dec 1, 2021 2:14:54 AM.

----- Compile Equations: Time Dependent in Study 1/Solution 1 (sol1) ---------->

#### Dependent Variables 3 (v3)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | [Time Dependent](#cs6296452) |

Initial values of variables solved for

| **Description** | **Value** |
| --- | --- |
| Method | Solution |
| Solution | [Solution 1](#cs9250785) |

Residual scaling

| **Description** | **Value** |
| --- | --- |
| Method | Manual |

Values of variables not solved for

| **Description** | **Value** |
| --- | --- |
| Method | Solution |
| Solution | [Solution 1](#cs9250785) |

Initial value calculation constants

| **Constant name** | **Initial value source** |
| --- | --- |
| t | range(0,0.2,3) |
| timestep | 0.003[s] |

Log

<---- Dependent Variables 3 in Study 1/Solution 1 (sol1) -----------------------

Started at Dec 1, 2021 2:15:01 AM.

Initial values of variables solved for: Solution 1 (sol1), Solution Store 2 (sol3), D=1E-11 m^2/s [Automatic].

Values of variables not solved for: Solution 1 (sol1), D=1E-11 [Automatic].

Solution time: 12 s.

Physical memory: 1.56 GB

Virtual memory: 2.27 GB

Ended at Dec 1, 2021 2:15:13 AM.

----- Dependent Variables 3 in Study 1/Solution 1 (sol1) ---------------------->

##### Concentration (comp1.c) (comp1\_c)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.c |
| Internal variables | {comp1.uflux.c, comp1.dflux.c, comp1.tds.dt2Inv\_c} |

##### Pressure (comp1.p) (comp1\_p)

General

| **Description** | **Value** |
| --- | --- |
| Field components | comp1.p |

##### Velocity field (comp1.u) (comp1\_u)

General

| **Description** | **Value** |
| --- | --- |
| Field components | {comp1.u, comp1.v, comp1.w} |
| Internal variables | {comp1.spf.isFluidHasBeenSolved, comp1.spf.dt2Inv\_u} |

##### Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf) (comp1\_spf\_inl1\_Pinlfdf)

General

| **Description** | **Value** |
| --- | --- |
| State components | comp1.spf.inl1.Pinlfdf |

##### Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf) (comp1\_spf\_inl2\_Pinlfdf)

General

| **Description** | **Value** |
| --- | --- |
| State components | comp1.spf.inl2.Pinlfdf |

#### Time-Dependent Solver 1 (t1)

General

| **Description** | **Value** |
| --- | --- |
| Defined by study step | [Time Dependent](#cs6296452) |
| Output times | {0, 0.2, 0.4, 0.6000000000000001, 0.8, 1, 1.2000000000000002, 1.4000000000000001, 1.6, 1.8, 2, 2.2, 2.4000000000000004, 2.6, 2.8000000000000003, 3} |
| Relative tolerance | 0.005 |

Absolute tolerance

| **Description** | **Value** |
| --- | --- |
| Tolerance method | Manual |
| Absolute tolerance | 5.0E-5 |

Field tolerance method

| **Field** | **Value** |
| --- | --- |
| Concentration (comp1.c) | Use\_global |
| Pressure (comp1.p) | Scaled |
| Velocity field (comp1.u) | Use\_global |
| Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf) | Use\_global |
| Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf) | Use\_global |

Field tolerance factor

| **Field** | **Value** |
| --- | --- |
| Concentration (comp1.c) | 0.1 |
| Pressure (comp1.p) | 1 |
| Velocity field (comp1.u) | 0.1 |
| Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf) | 0.1 |
| Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf) | 0.1 |

Time stepping

| **Description** | **Value** |
| --- | --- |
| Maximum BDF order | 2 |
| Nonlinear controller | On |
| Fraction of initial step for Backward Euler | 0.01 |
| Error estimation | Exclude algebraic |

Log

<---- Time-Dependent Solver 1 in Study 1/Solution 1 (sol1) ---------------------

Started at Dec 1, 2021 2:15:13 AM.

Time-dependent solver (BDF)

Number of degrees of freedom solved for: 406544 (plus 67254 internal DOFs).

Nonsymmetric matrix found.

Scales for dependent variables:

Pressure (comp1.p): 8.9

Velocity field (comp1.u): 7.5

Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf): 73

Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf): 52

Orthonormal null-space function used.

Nonsymmetric matrix found.

Scales for dependent variables:

Concentration (comp1.c): 10

Orthonormal null-space function used.

Nonsymmetric matrix found.

Step        Time    Stepsize      Res  Jac  Sol Order Tfail NLfail LinIt   LinErr   LinRes

   0           0           - out   16    6   16                  0

                   Group #1:        8    3    8                      134    0.002   0.0006

                   Group #2:        8    3    8                       58   0.0017  1.5e-06

   1       0.003       0.003       24    8   24     1     0      0

                   Group #1:       12    4   12                      150   0.0009        -

                   Group #2:       12    4   12                       71   0.0019        -

   2       0.006       0.003       32   10   32     1     0      0

                   Group #1:       16    5   16                      161  0.00048        -

                   Group #2:       16    5   16                       83   0.0016        -

   3   0.0098495   0.0038495       54   14   54     1     1      0

                   Group #1:       27    7   27                      184  0.00029        -

                   Group #2:       27    7   27                      115   0.0016        -

   4    0.013699   0.0038495       64   16   64     1     1      0

                   Group #1:       32    8   32                      194  0.00011        -

                   Group #2:       32    8   32                      129  0.00094        -

   5    0.017548   0.0038495       66   18   66     1     1      0

                   Group #1:       33    9   33                      201    0.002        -

                   Group #2:       33    9   33                      135   0.0016        -

   6    0.025247    0.007699       74   20   74     1     1      0

                   Group #1:       37   10   37                      209  6.2e-05        -

                   Group #2:       37   10   37                      147    0.001        -

   7    0.032946    0.007699       76   22   76     1     1      0

                   Group #1:       38   11   38                      214   0.0014        -

                   Group #2:       38   11   38                      153  0.00087        -

   8    0.048344    0.015398       80   24   80     1     1      0

                   Group #1:       40   12   40                      220  0.00043        -

                   Group #2:       40   12   40                      162   0.0003        -

   9    0.063742    0.015398       84   26   84     1     1      0

                   Group #1:       42   13   42                      229  6.7e-05        -

                   Group #2:       42   13   42                      170   0.0015        -

  10    0.094538    0.030796       94   28   94     1     1      0

                   Group #1:       47   14   47                      239  7.6e-06        -

                   Group #2:       47   14   47                      187   0.0011        -

  11     0.12533    0.030796       96   30   96     1     1      0

                   Group #1:       48   15   48                      247   0.0016        -

                   Group #2:       48   15   48                      196   0.0011        -

  12     0.18693    0.061592      100   32  100     1     1      0

                   Group #1:       50   16   50                      256    3e-05        -

                   Group #2:       50   16   50                      210  0.00091        -

   -         0.2           - out

  13     0.24852    0.061592      104   34  104     1     1      0

                   Group #1:       52   17   52                      265  8.4e-06        -

                   Group #2:       52   17   52                      224  0.00074        -

  14      0.3717     0.12318      108   36  108     1     1      0

                   Group #1:       54   18   54                      276  8.9e-06        -

                   Group #2:       54   18   54                      242    0.001        -

   -         0.4           - out

  15     0.49489     0.12318      112   38  112     1     1      0

                   Group #1:       56   19   56                      288  3.8e-06        -

                   Group #2:       56   19   56                      261   0.0022        -

   -         0.6           - out

  16     0.74125     0.24637      118   40  118     1     1      0

                   Group #1:       59   20   59                      299    9e-06        -

                   Group #2:       59   20   59                      290   0.0021        -

   -         0.8           - out

  17     0.98762     0.24637      122   42  122     1     1      0

                   Group #1:       61   21   61                      316  6.5e-06        -

                   Group #2:       61   21   61                      316   0.0016        -

   -           1           - out

   -         1.2           - out

  18      1.2876         0.3      126   44  126     1     1      0

                   Group #1:       63   22   63                      329  2.1e-06        -

                   Group #2:       63   22   63                      345   0.0021        -

   -         1.4           - out

  19      1.5876         0.3      130   46  130     1     1      0

                   Group #1:       65   23   65                      344  2.3e-06        -

                   Group #2:       65   23   65                      372   0.0019        -

   -         1.6           - out

   -         1.8           - out

  20      1.8876         0.3      134   48  134     1     1      0

                   Group #1:       67   24   67                      357  2.4e-06        -

                   Group #2:       67   24   67                      403   0.0019        -

   -           2           - out

  21      2.1876         0.3      136   50  136     1     1      0

                   Group #1:       68   25   68                      367   0.0023        -

                   Group #2:       68   25   68                      428   0.0024        -

   -         2.2           - out

   -         2.4           - out

  22      2.4876         0.3      138   52  138     1     1      0

                   Group #1:       69   26   69                      380    0.002        -

                   Group #2:       69   26   69                      451   0.0024        -

   -         2.6           - out

  23      2.7876         0.3      146   54  146     1     1      0

                   Group #1:       73   27   73                      395  5.9e-07        -

                   Group #2:       73   27   73                      489   0.0019        -

   -         2.8           - out

   -           3           - out

  24      3.0876         0.3      150   56  150     1     1      0

                   Group #1:       75   28   75                      410  3.3e-07        -

                   Group #2:       75   28   75                      520   0.0017        -

Time-stepping completed.

Solution time: 8773 s. (2 hours, 26 minutes, 13 seconds)

Physical memory: 4.84 GB

Virtual memory: 6.35 GB

Ended at Dec 1, 2021 4:41:26 AM.

----- Time-Dependent Solver 1 in Study 1/Solution 1 (sol1) -------------------->

##### Advanced (aDef)

Assembly settings

| **Description** | **Value** |
| --- | --- |
| Reuse sparsity pattern | On |

##### Segregated 1 (se1)

General

| **Description** | **Value** |
| --- | --- |
| Tolerance factor | 0.5 |
| Stabilization and acceleration | Anderson acceleration |
| Dimension of iteration space | 5 |
| Mixing parameter | 0.9 |
| Iteration delay | 1 |

###### Velocity u, Pressure p (ss1)

General

| **Description** | **Value** |
| --- | --- |
| Variables | {Velocity field (comp1.u), Pressure (comp1.p), Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf), Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf)} |
| Linear solver | [AMG, fluid flow variables (spf)](#cs8951236) |

Method and termination

| **Description** | **Value** |
| --- | --- |
| Damping factor | 0.8 |
| Jacobian update | Once per time step |

###### Concentration c (ss2)

General

| **Description** | **Value** |
| --- | --- |
| Variables | Concentration (comp1.c) |
| Linear solver | [AMG, concentrations (tds)](#cs8478324) |

Method and termination

| **Description** | **Value** |
| --- | --- |
| Damping factor | 0.8 |
| Jacobian update | Once per time step |

##### AMG, fluid flow variables (spf) (i1)

General

| **Description** | **Value** |
| --- | --- |
| Maximum number of iterations | 100 |

Error

| **Description** | **Value** |
| --- | --- |
| Factor in error estimate | 20 |

###### Multigrid 1 (mg1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | Smoothed aggregation AMG |
| Maximum number of DOFs at coarsest level | 80000 |
| Strength of connections | 0.02 |
| Construct prolongators componentwise | On |
| Prolongator smoothing | Off |

Presmoother (pr)

Vanka 1 (va1)

Main

| **Description** | **Value** |
| --- | --- |
| Sweep type | SSOR |
| Number of iterations | 0 |
| Variables | {Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf), Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf), Pressure (comp1.p)} |

Secondary

| **Description** | **Value** |
| --- | --- |
| Relaxation factor | 0.5 |

Postsmoother (po)

Vanka 1 (va1)

Main

| **Description** | **Value** |
| --- | --- |
| Sweep type | SSOR |
| Number of iterations | 1 |
| Variables | {Help ode variable for fully developed flow (comp1.spf.inl1.Pinlfdf), Help ode variable for fully developed flow (comp1.spf.inl2.Pinlfdf), Pressure (comp1.p)} |

Secondary

| **Description** | **Value** |
| --- | --- |
| Number of secondary iterations | 2 |
| Relaxation factor | 0.5 |

Coarse Solver (cs)

Direct 1 (d1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | PARDISO |
| Pivoting perturbation | 1.0E-13 |

##### AMG, concentrations (tds) (i2)

General

| **Description** | **Value** |
| --- | --- |
| Maximum number of iterations | 50 |

###### Multigrid 1 (mg1)

General

| **Description** | **Value** |
| --- | --- |
| Solver | Smoothed aggregation AMG |
| Maximum number of DOFs at coarsest level | 50000 |
| Construct prolongators componentwise | On |
| Prolongator smoothing | Off |

Presmoother (pr)

SOR Line 1 (sl1)

Main

| **Description** | **Value** |
| --- | --- |
| Sweep type | SSOR |
| Number of iterations | 1 |
| Relaxation factor | 0.7 |

Secondary

| **Description** | **Value** |
| --- | --- |
| Relaxation factor | 0.5 |

Postsmoother (po)

SOR Line 1 (sl1)

Main

| **Description** | **Value** |
| --- | --- |
| Sweep type | SSOR |
| Number of iterations | 1 |
| Relaxation factor | 0.7 |

Secondary

| **Description** | **Value** |
| --- | --- |
| Relaxation factor | 0.5 |

Coarse Solver (cs)

Direct 1 (d1)

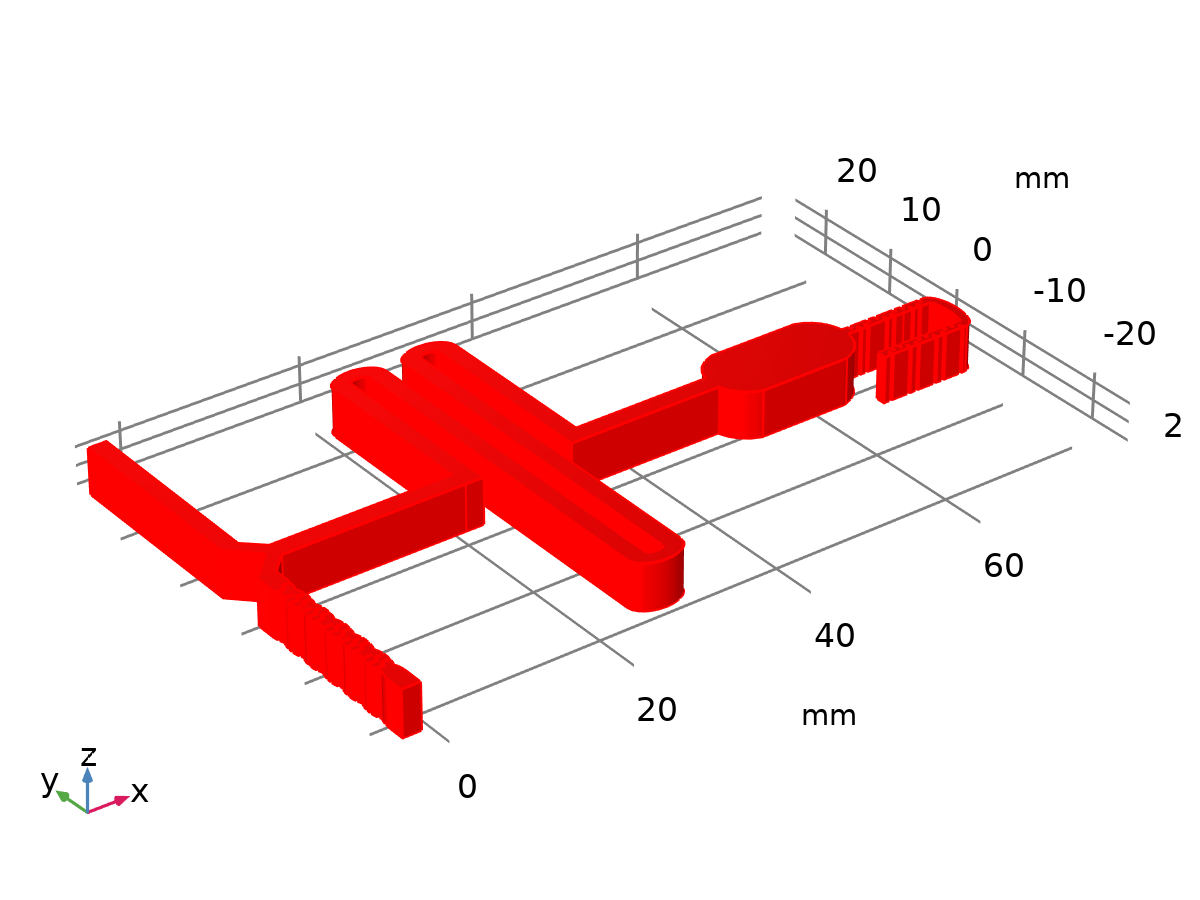
General

| **Description** | **Value** |
| --- | --- |
| Solver | PARDISO |
| Pivoting perturbation | 1.0E-13 |

1. Results
   1. Datasets
      1. Study 1/Solution 1

Solution

| **Description** | **Value** |
| --- | --- |
| Solution | [Solution 1](#cs9250785) |
| Component | Component 1 (comp1) |

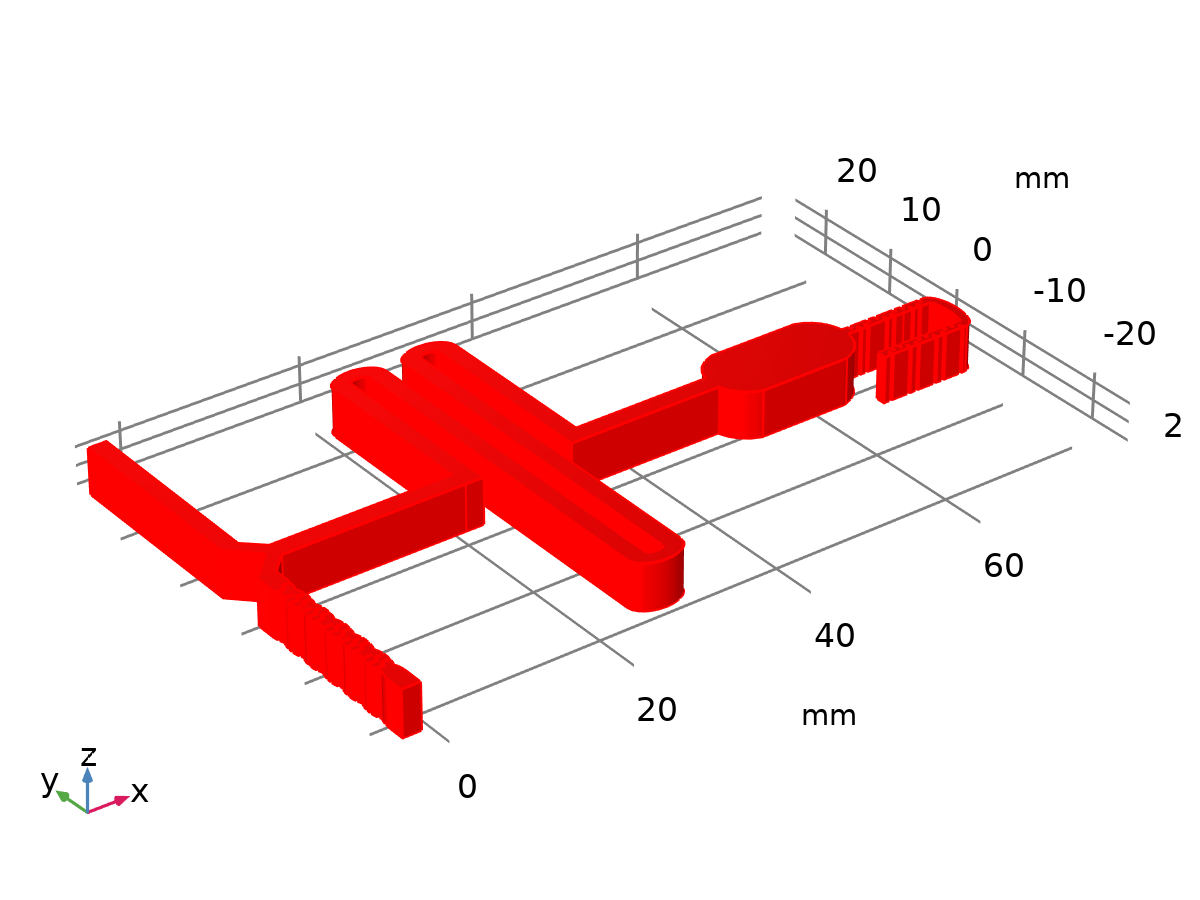


Dataset: Study 1/Solution 1

* + 1. Study 1/Solution Store 1

Solution

| **Description** | **Value** |
| --- | --- |
| Solution | Solution Store 1 |
| Component | Component 1 (comp1) |

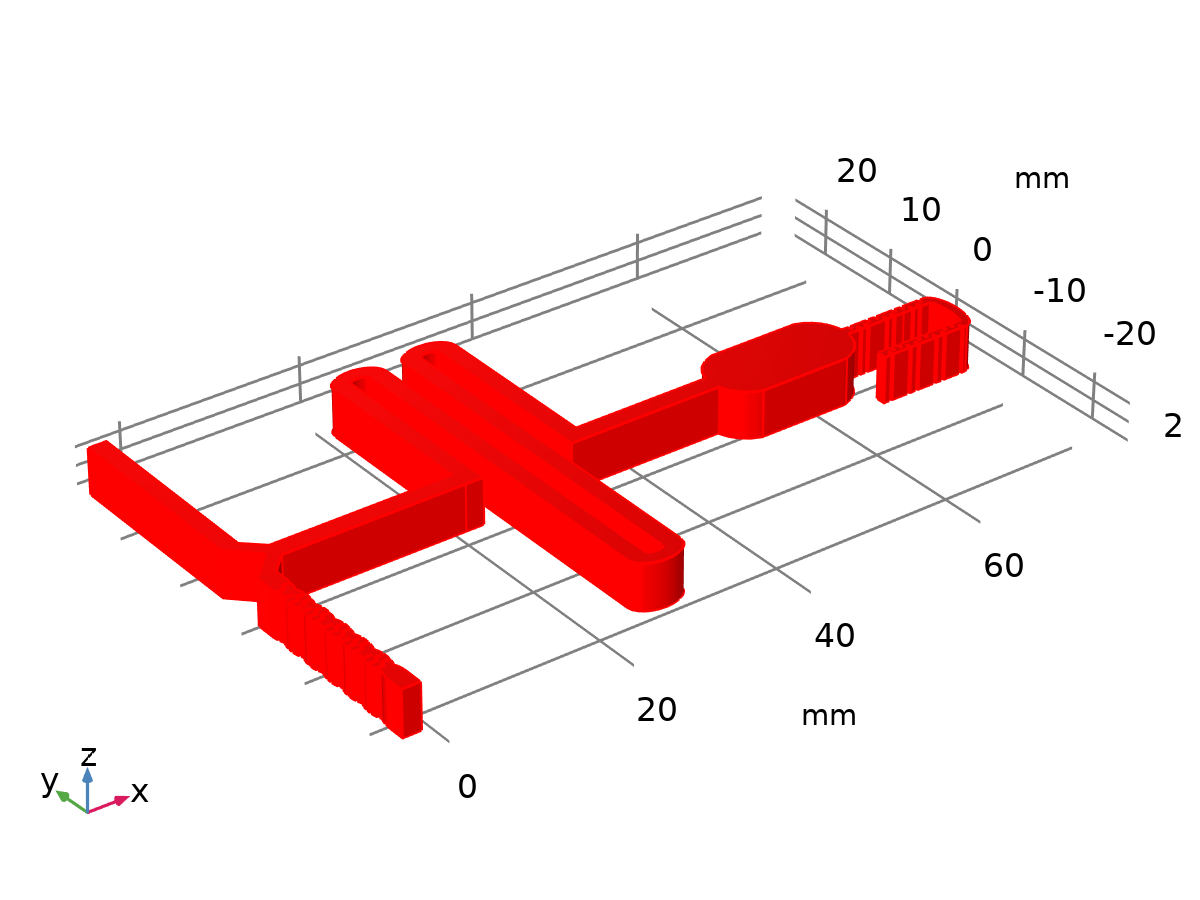


Dataset: Study 1/Solution Store 1

* + 1. Study 1/Solution Store 2

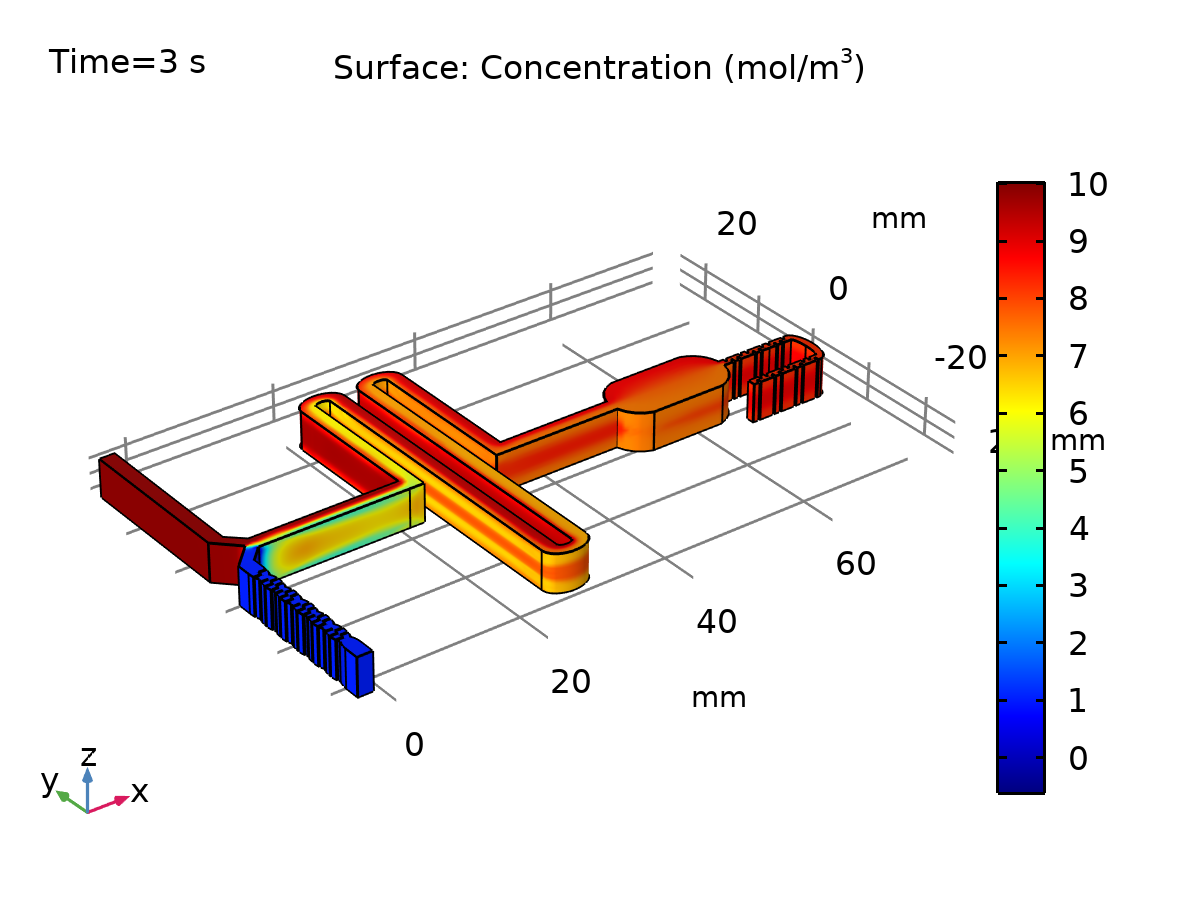
Solution

| **Description** | **Value** |
| --- | --- |
| Solution | Solution Store 2 |
| Component | Component 1 (comp1) |



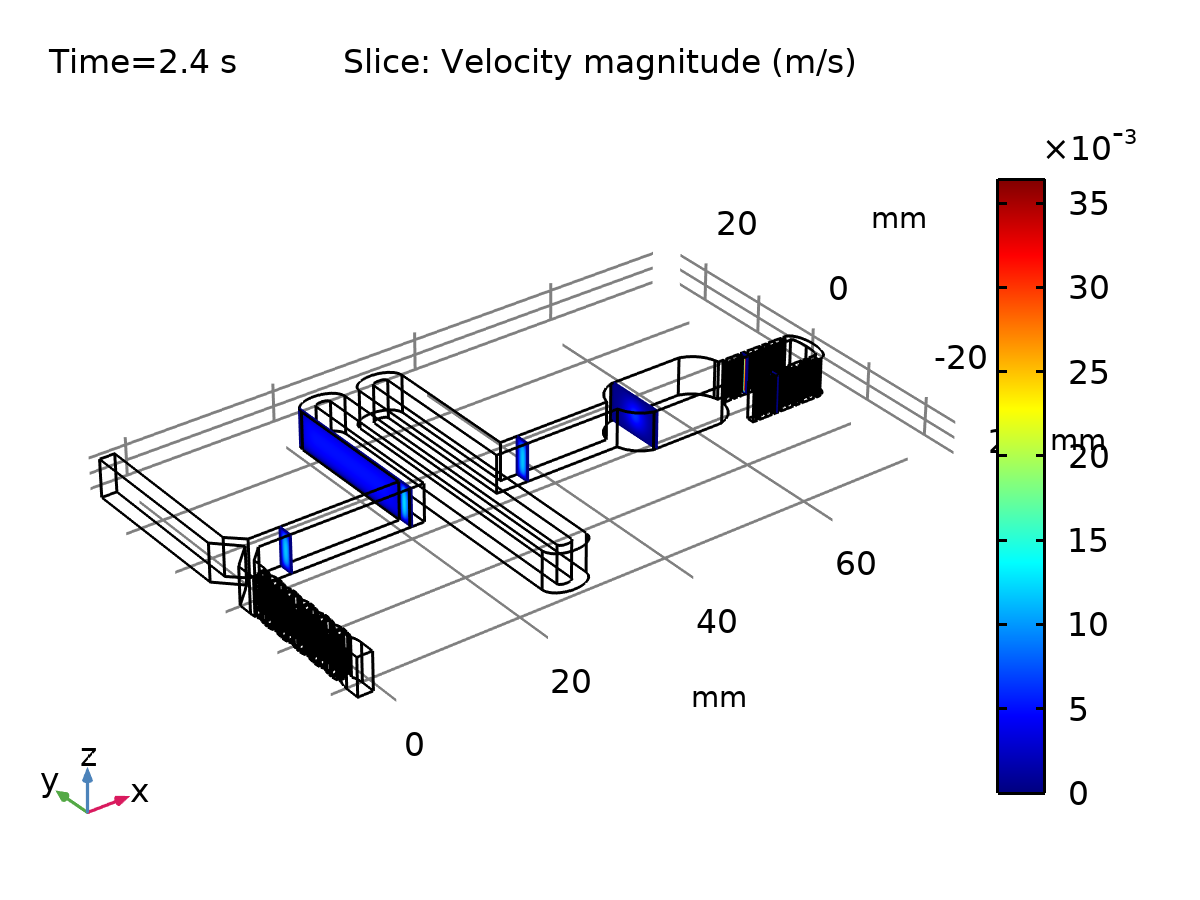
Dataset: Study 1/Solution Store 2

* 1. Plot Groups
     1. Concentration, Surface (tds)



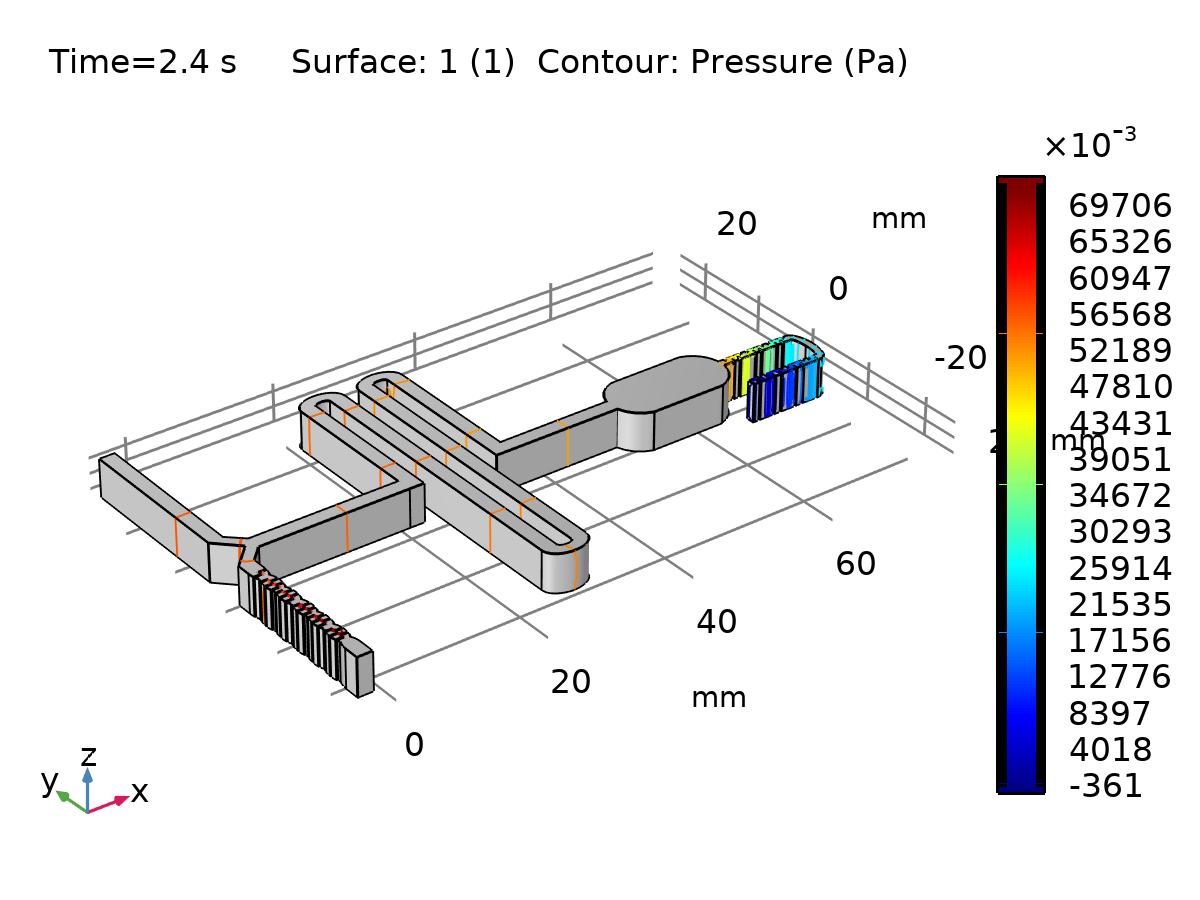
Surface: Concentration (mol/m3)

* + 1. Velocity (spf)



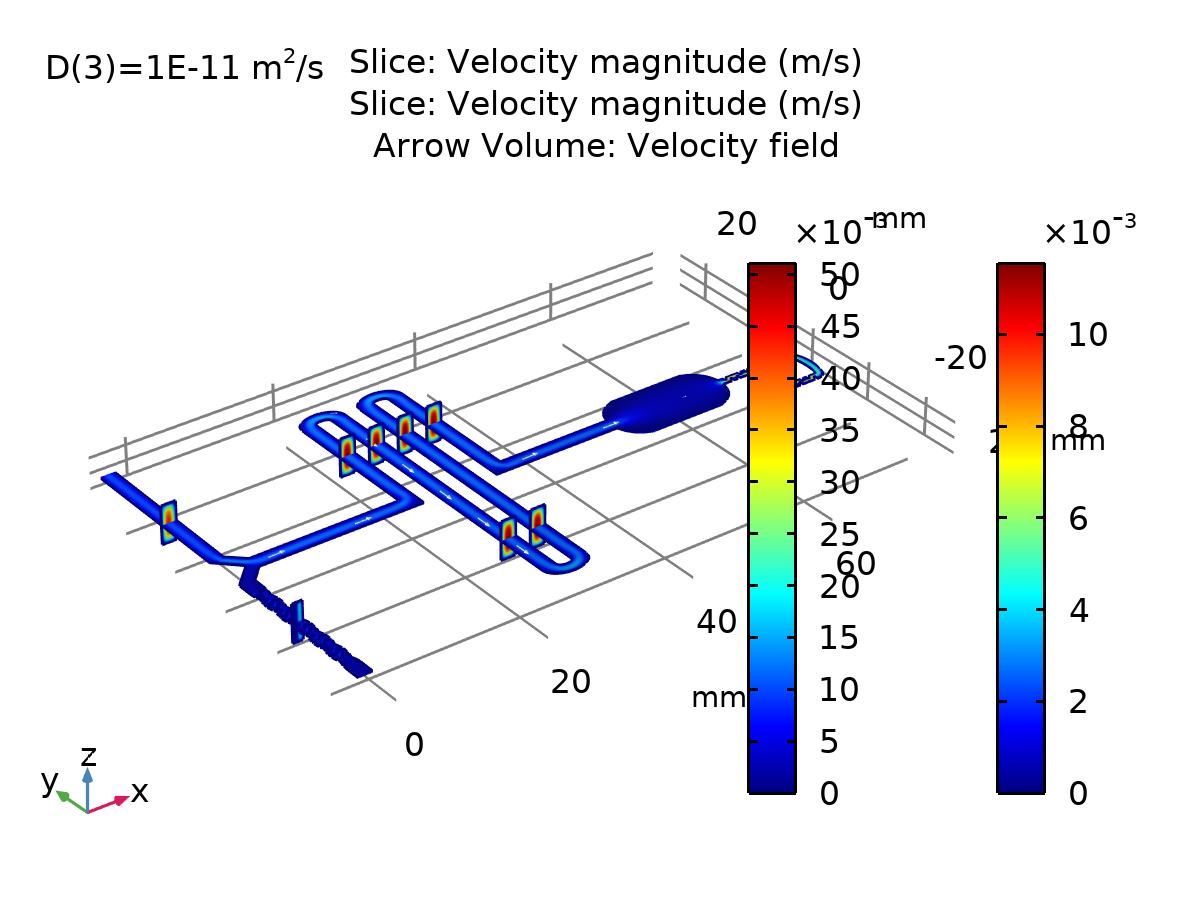
Slice: Velocity magnitude (m/s)

* + 1. Pressure (spf)



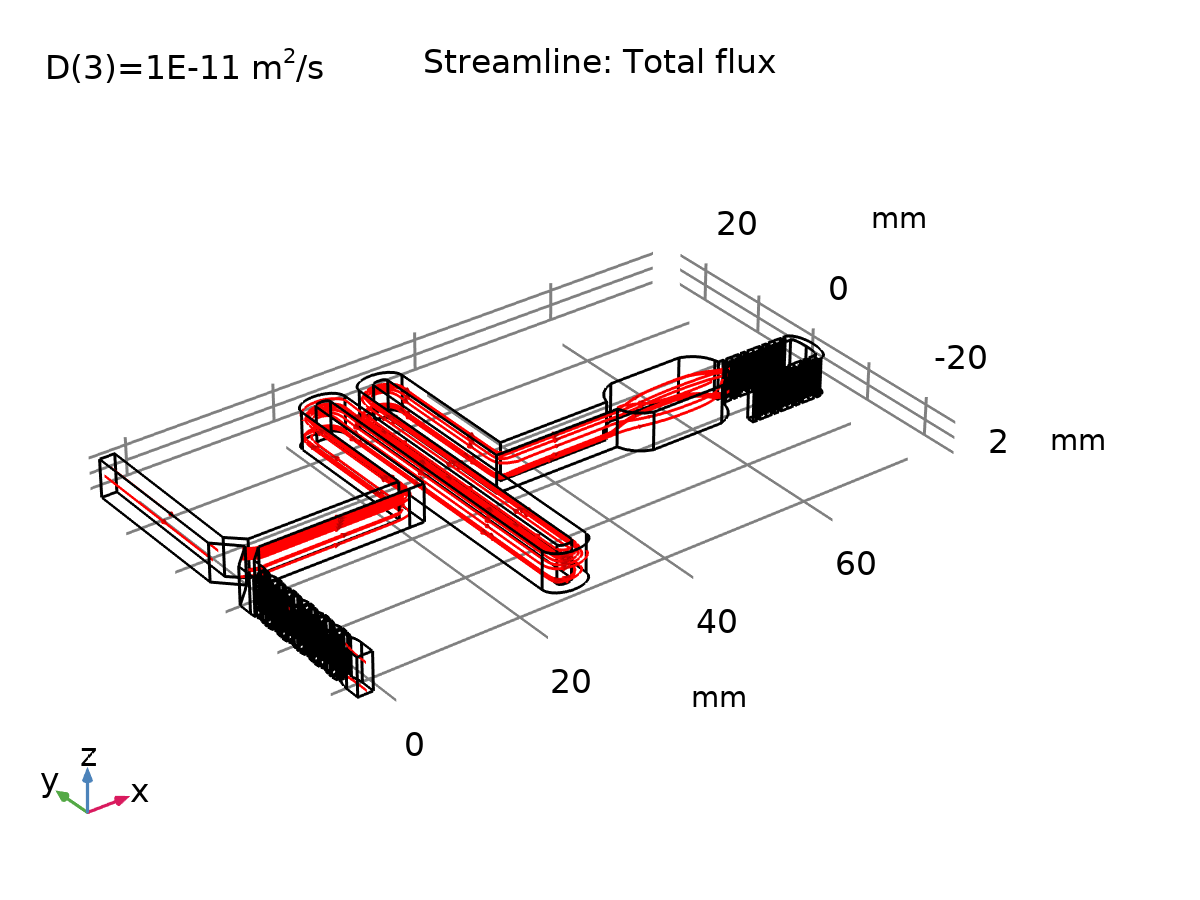
Surface: 1 (1) Contour: Pressure (Pa)

* + 1. Velocity 3D



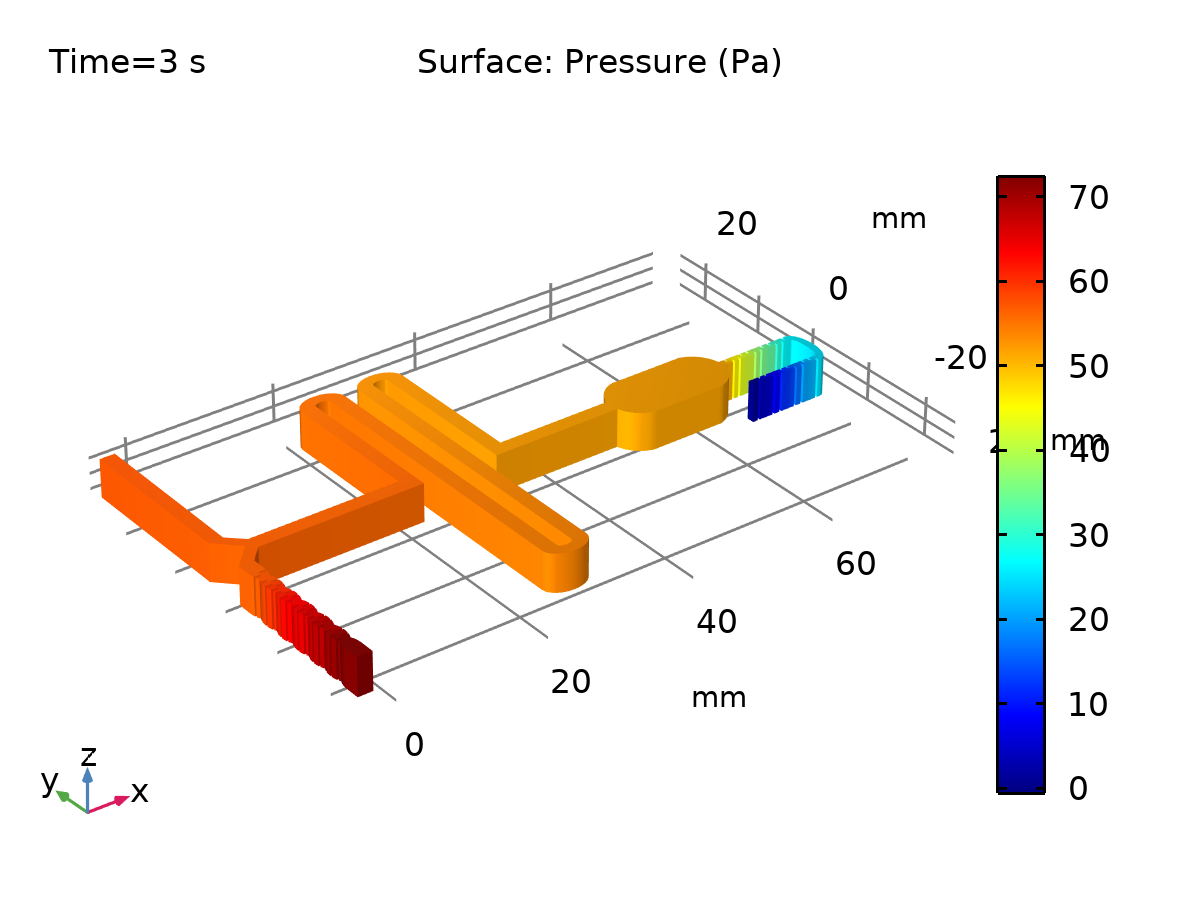
Slice: Velocity magnitude (m/s) Slice: Velocity magnitude (m/s) Arrow Volume: Velocity field

* + 1. Concentration, Streamline (tds)



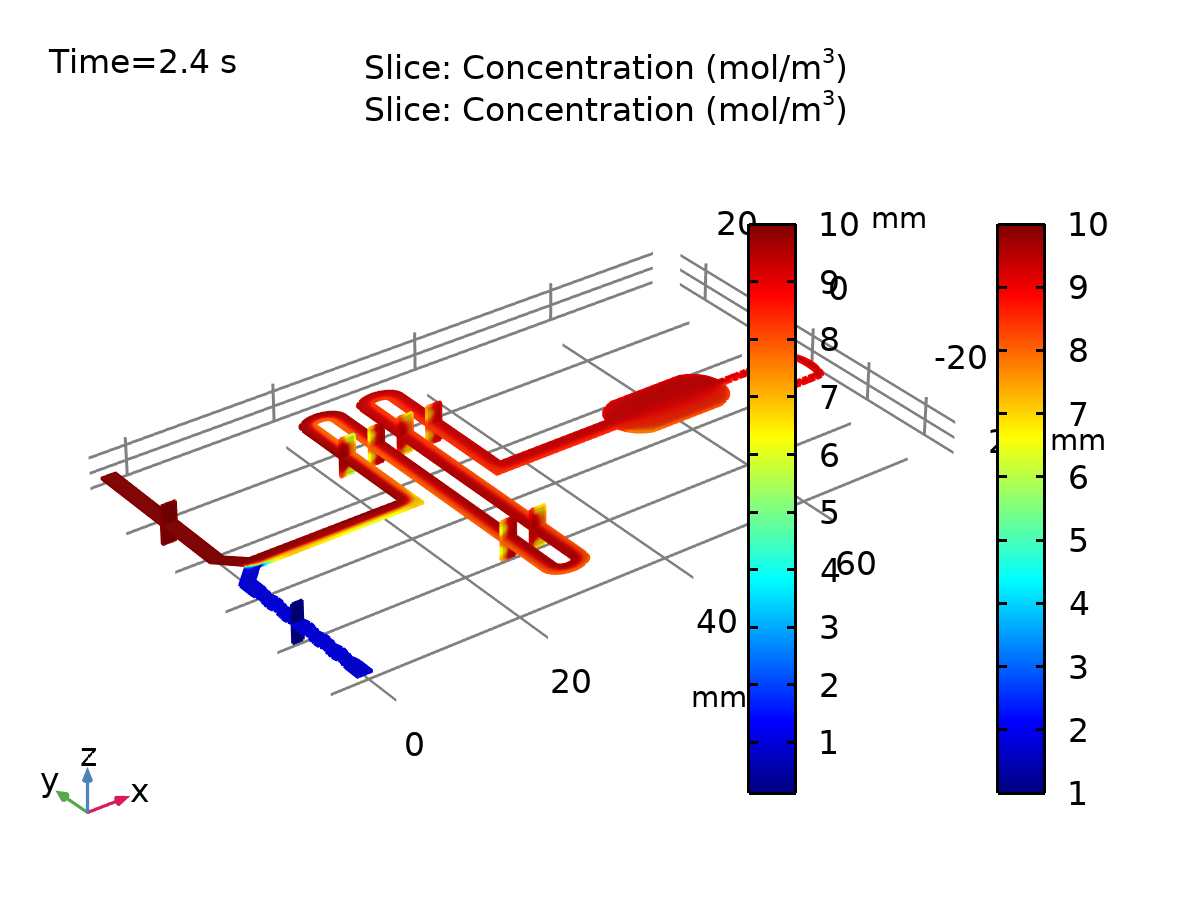
Streamline: Total flux

* + 1. Pressure 3D



Surface: Pressure (Pa)

* + 1. Concentration 3D



Slice: Concentration (mol/m3) Slice: Concentration (mol/m3)