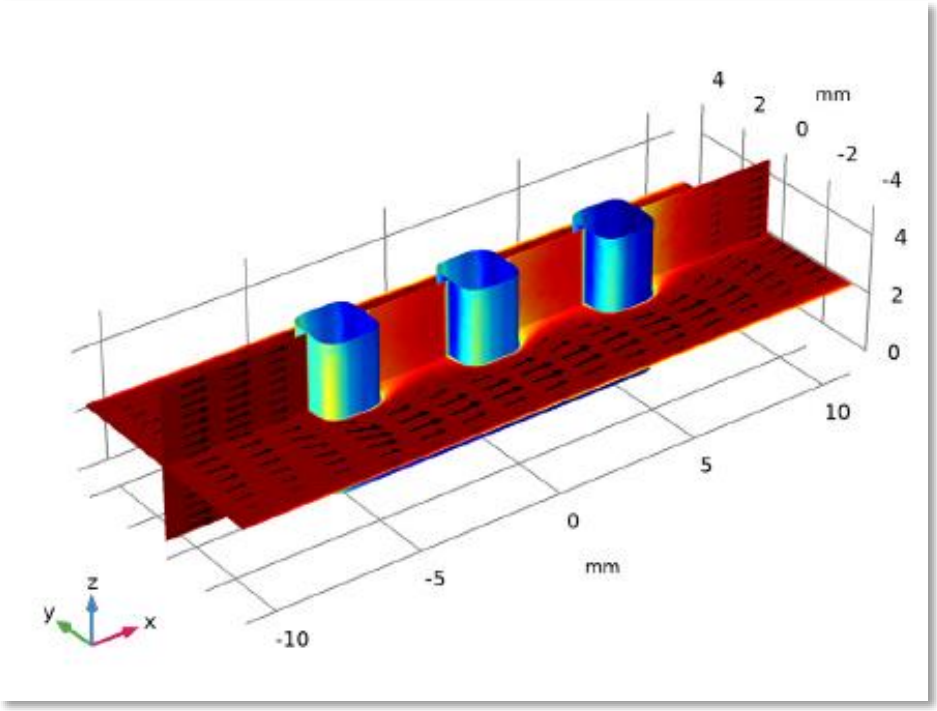
ALEXANDRIA UNIVERSITY

HEAT TRANSFER

NUMERICAL SOLUTION PROJECT



Group11	ID
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Train

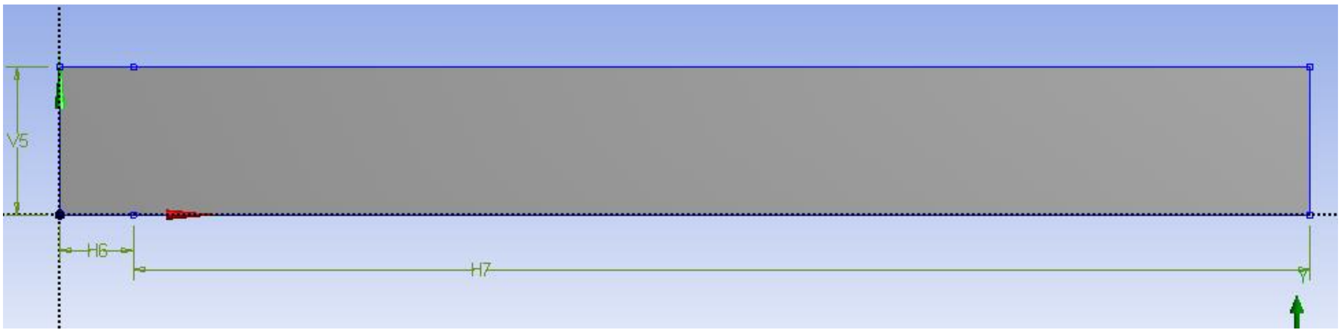
Description

This problem is modelled as a steady-state, 2-D Forced convection problem, taking into consideration the domain entrance Region and the domain height

Numerical Calculation

The numerical solution is done on **ANSYS**, using the **SIMPLEC** solver, for the initial solution and Adapting mesh to Velocity gradient to capture the Velocity boundary layer.

Geometry

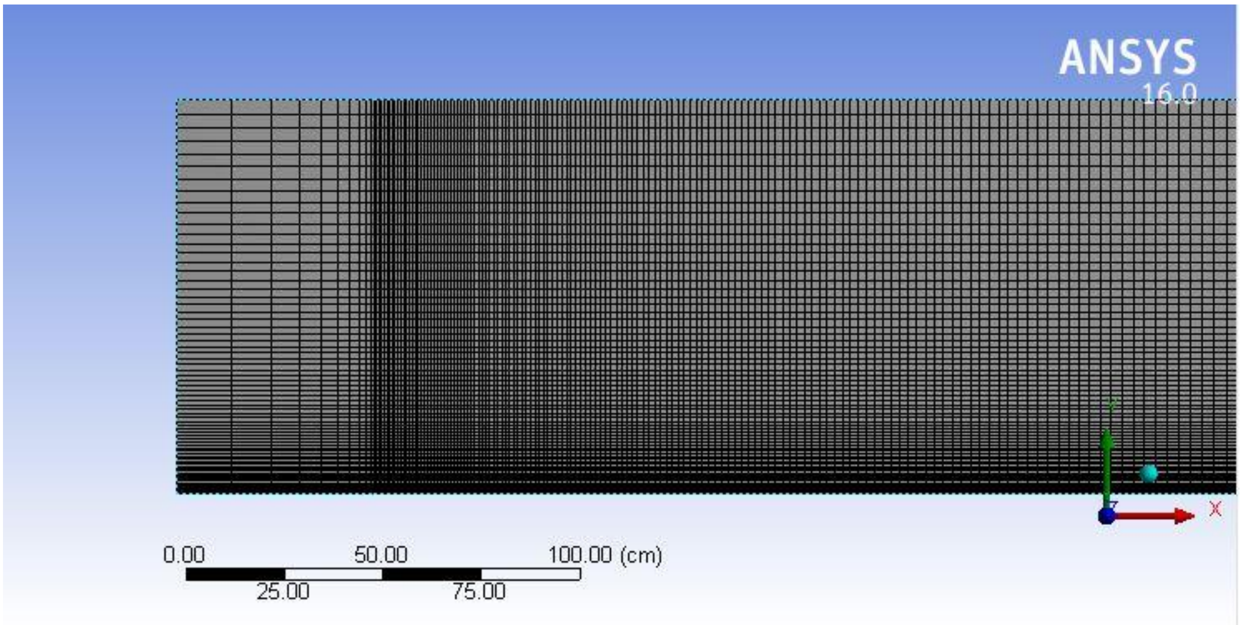


V5: Is the domain height

H6: Is the Domain Entrance

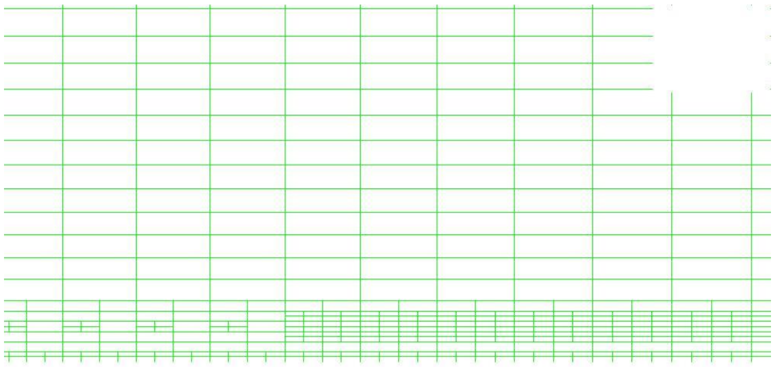
Mesh

Edge sizing is utilized to ensure small enough elements near leading edge of plate to capture gradients



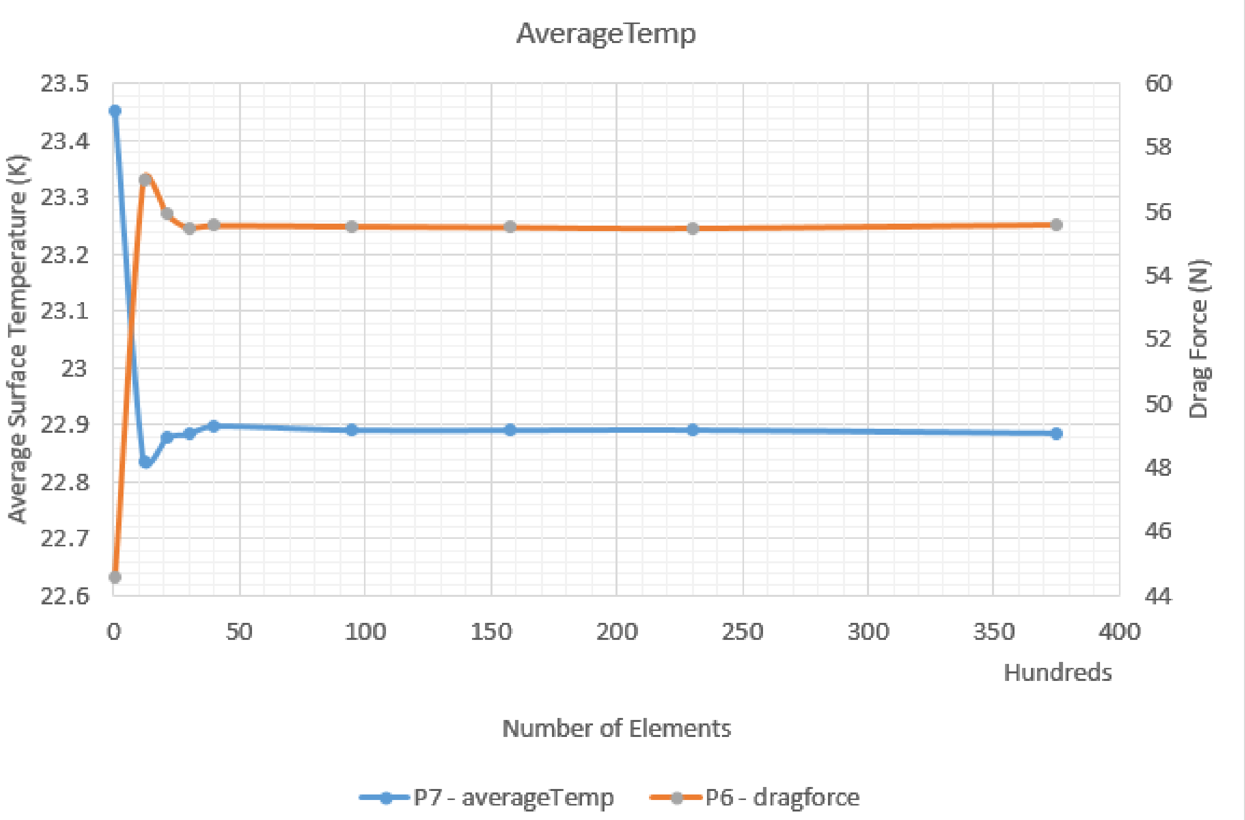
Adapting mesh

The mesh is adapted after initial solution to the velocity gradients to ensure presence of enough elements inside the velocity boundary



Mesh dependency Study

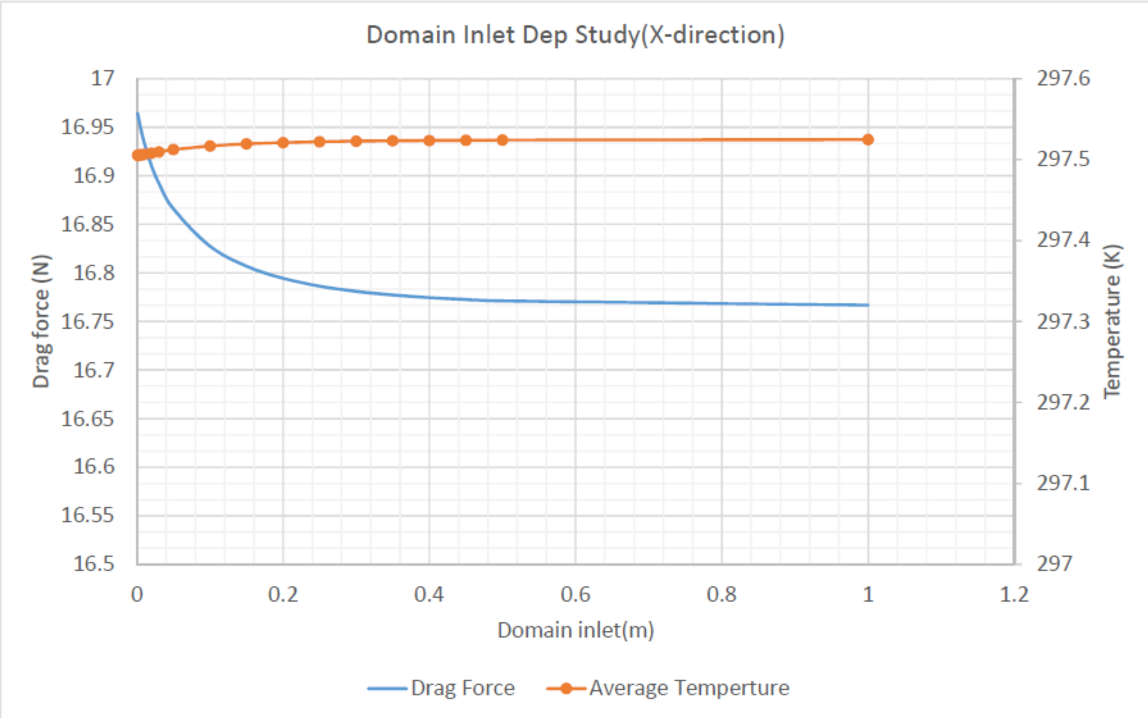
The meh is varied from extremely coarse to extremely fine to ensure the solution is mesh-independent, the parameters of concern are average surface temperature and drag force, the results are shown



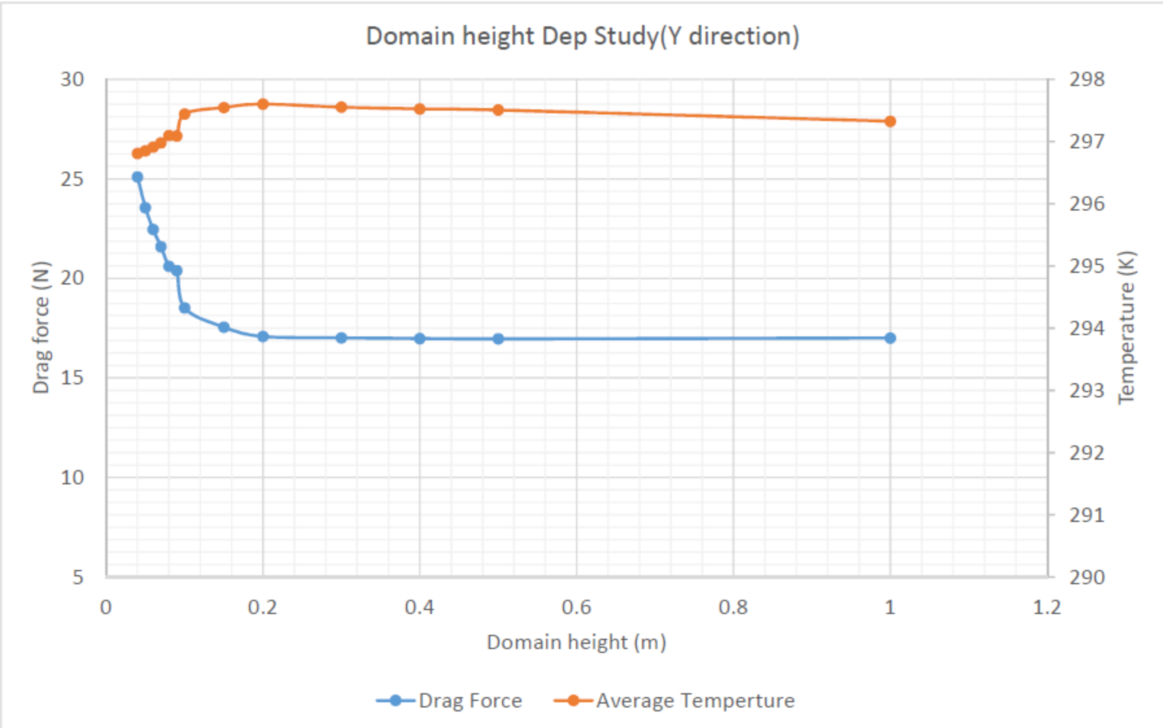
The solution for both parameters converges after about, 10 thousand elements.

Domain Dependency study

X-direction (Domain Inlet)



Y-direction (Domain Height)



The Surface temperature is nearly independent of the domain but the force is affected due to V.B.L deterioration if the inlet is close to the no-slip region.

Time step dependency Study

The Study Is Steady-State So no time step dependency is done

Hand Calculation

The problem is solved by hand using the available correlations [Incropera](7-20 to 7-30)

Equations

Shown In Figure

Formatted Equations

$$T_f = 1/2 \cdot (T_{guess} + T_{inf})$$

$$Re = \frac{\rho \cdot Vel \cdot L_c}{\mu}$$

$$Nus = 0.0308 \cdot Re^{[4/5]} \cdot Pr^{[1/3]}$$

$$\nu = \frac{\mu}{\rho}$$

$$\mu = \mathbf{Visc}(Air_{ha}, T=T_f, P=P)$$

$$\rho = \rho(Air_{ha}, T=T_f, P=P)$$

$$Pr = \mathbf{Pr}(Air_{ha}, T=T_f, P=P)$$

$$k = \mathbf{k}(Air_{ha}, T=T_f, P=P)$$

$$Nus = \frac{h \cdot L_c}{k}$$

$$q = h \cdot (T_s - T_{inf})$$

$$C_f = \frac{0.074}{Re^{[1/5]}} - \frac{1742}{Re}$$

$$F_d = 0.5 \cdot \rho \cdot Vel^2 \cdot C_f \cdot A$$

Results

vel	T(K)		h	
	hand Calc	Numerical	hand Calc	Numerical
0	55.00	82.00	5.68	3.36
10	29.60	29.13	20.00	22.63
20	25.49	24.85	36.40	43.00
30	23.97	23.67	50.42	55.96
40	23.15	22.89	63.00	71.11
vel	F(N)		C_f*e-3	
	hand Calc	Numerical	hand Calc	Numerical
0	0.00	0.00	0.00	0.00
10	3.96	4.39	2.93	3.25
20	14.56	15.51	2.70	2.87
30	30.78	32.53	2.53	2.68
40	52.00	55.60	2.41	2.57

Plots

Required

1-The Relation between the Velocity and change in both velocity and Drag Force

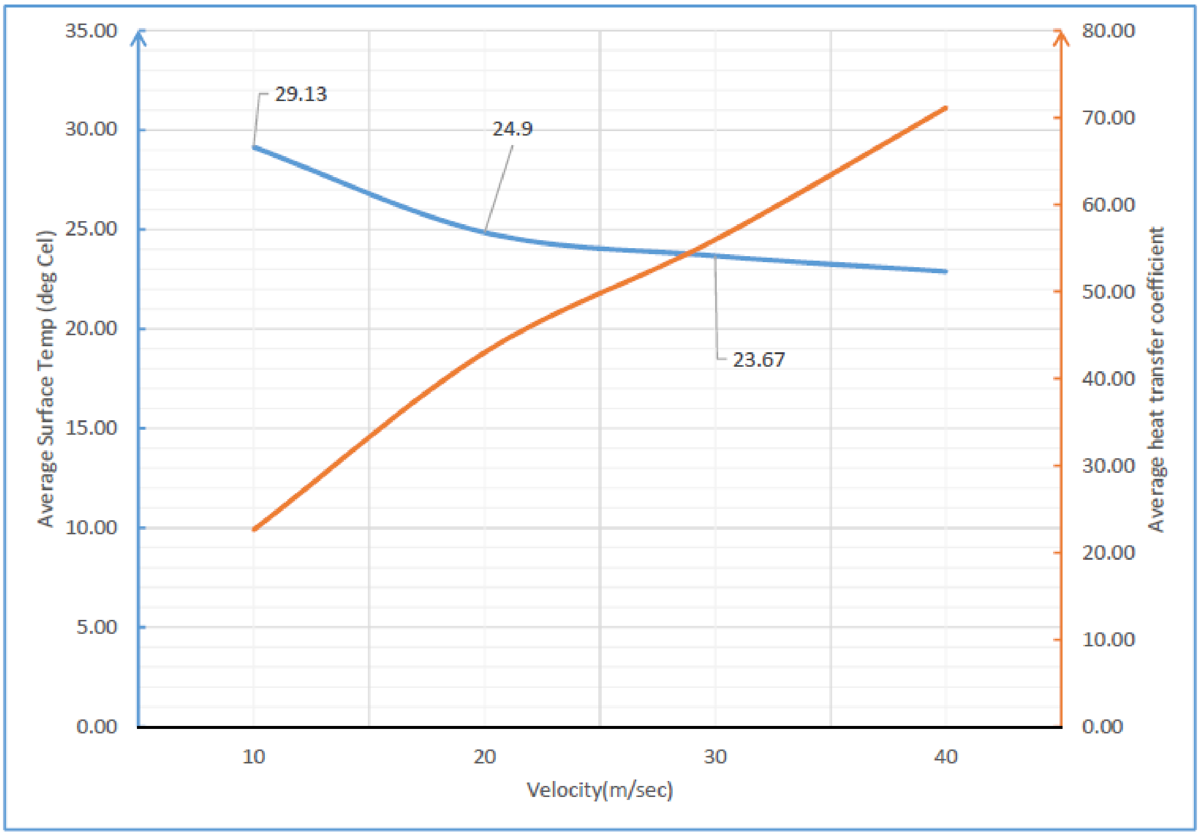
2- The Relation between the Velocity and change in both Roof Temp. And Heat Transfer Coefficient

3-Comparison between Drag forces obtained from analytical and numerical method

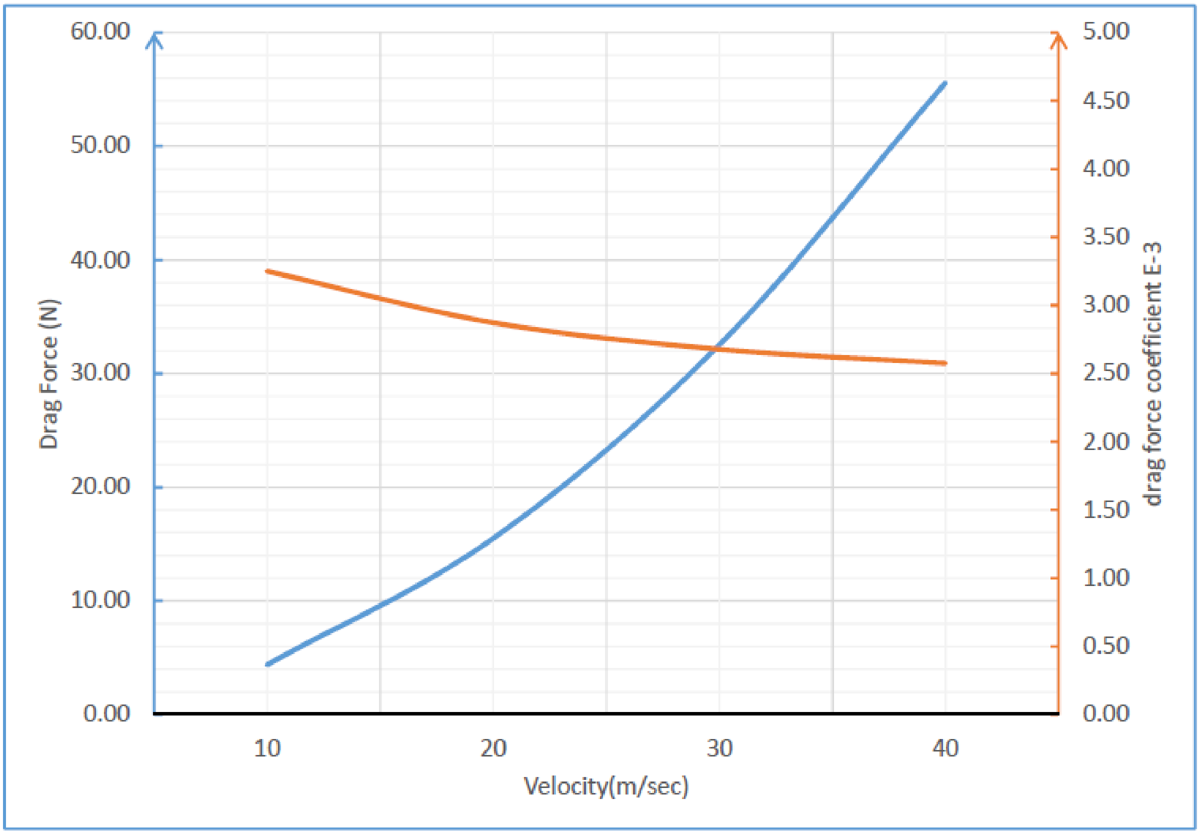
3-Comparison between Surface Temp. Obtained from analytical and numerical method

Heat Transfer
Fall 2019 Course Project

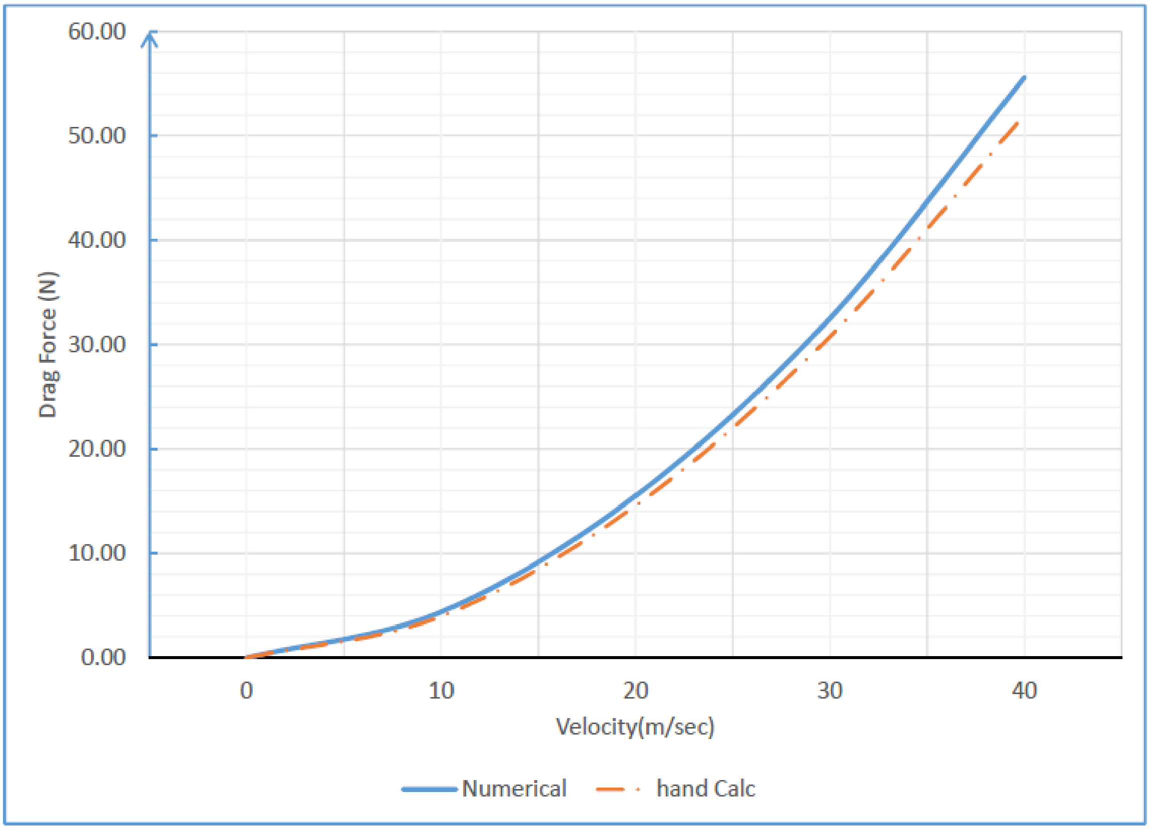
1-



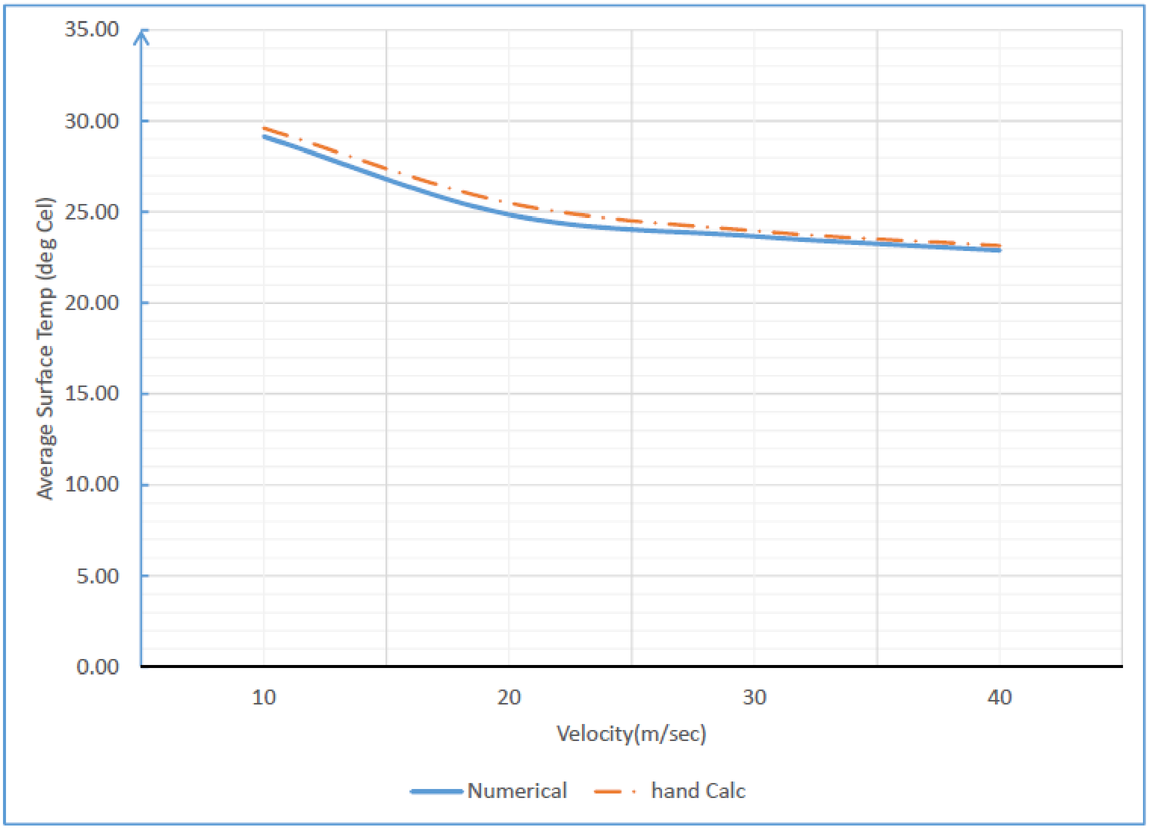
2-



3-


60.00
50.00
40.00
30.00
20.00
10.00
0.00
Drag Force (N)
0
10
20
30
40
Velocity(m/sec)
Numerical
hand Calc

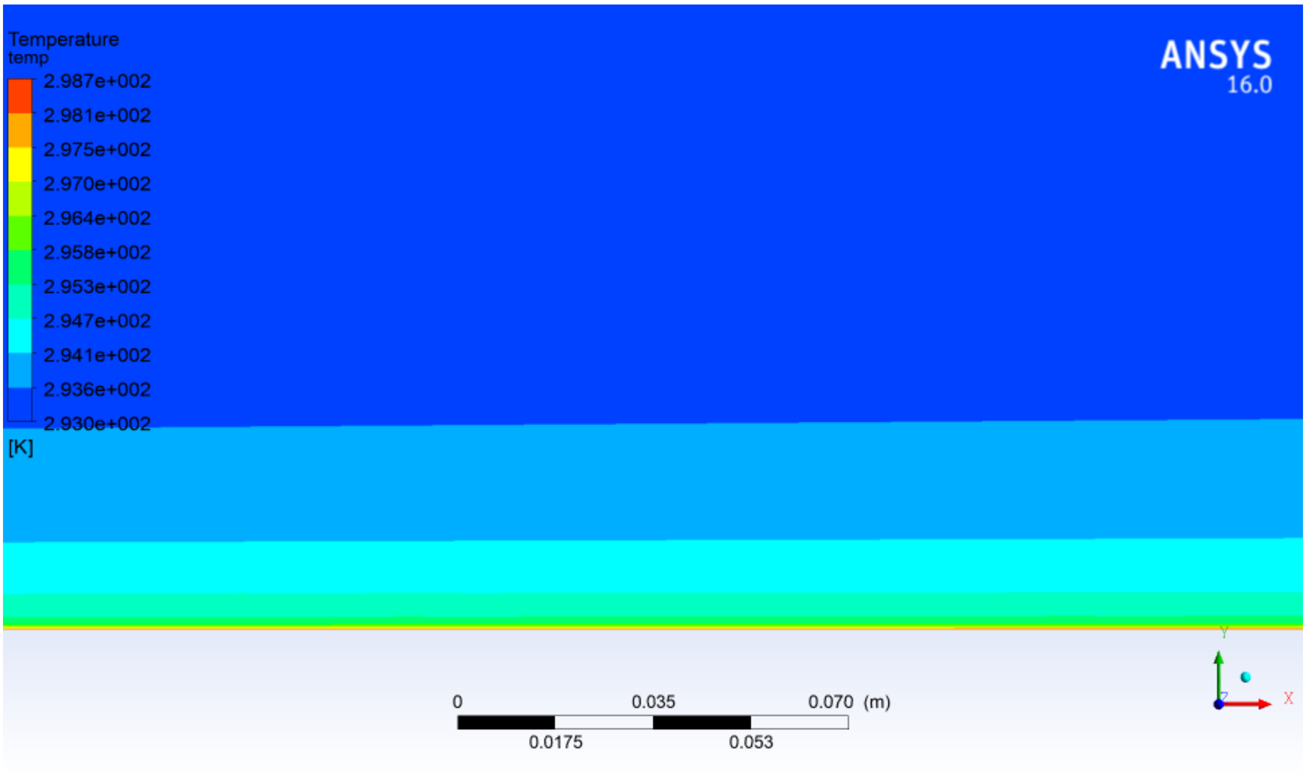
4-


35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Average Surface Temp (deg Cel)
10
20
30
40
Velocity(m/sec)
Numerical
hand Calc

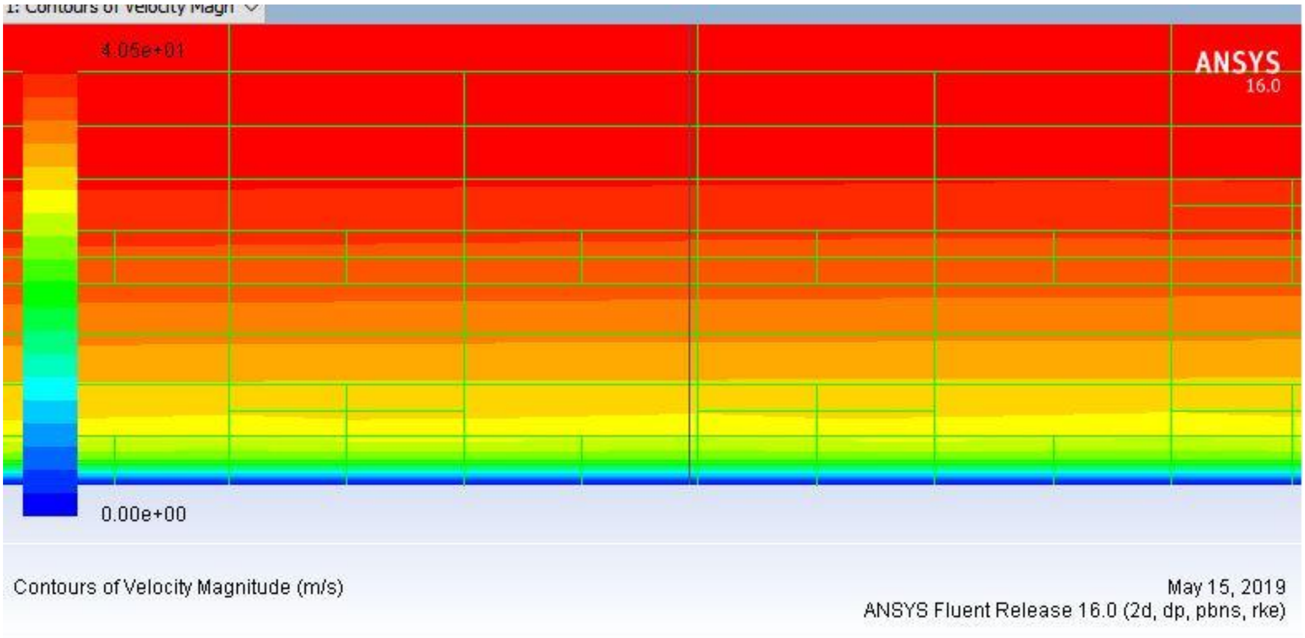
Graphics

Contours

Temperature

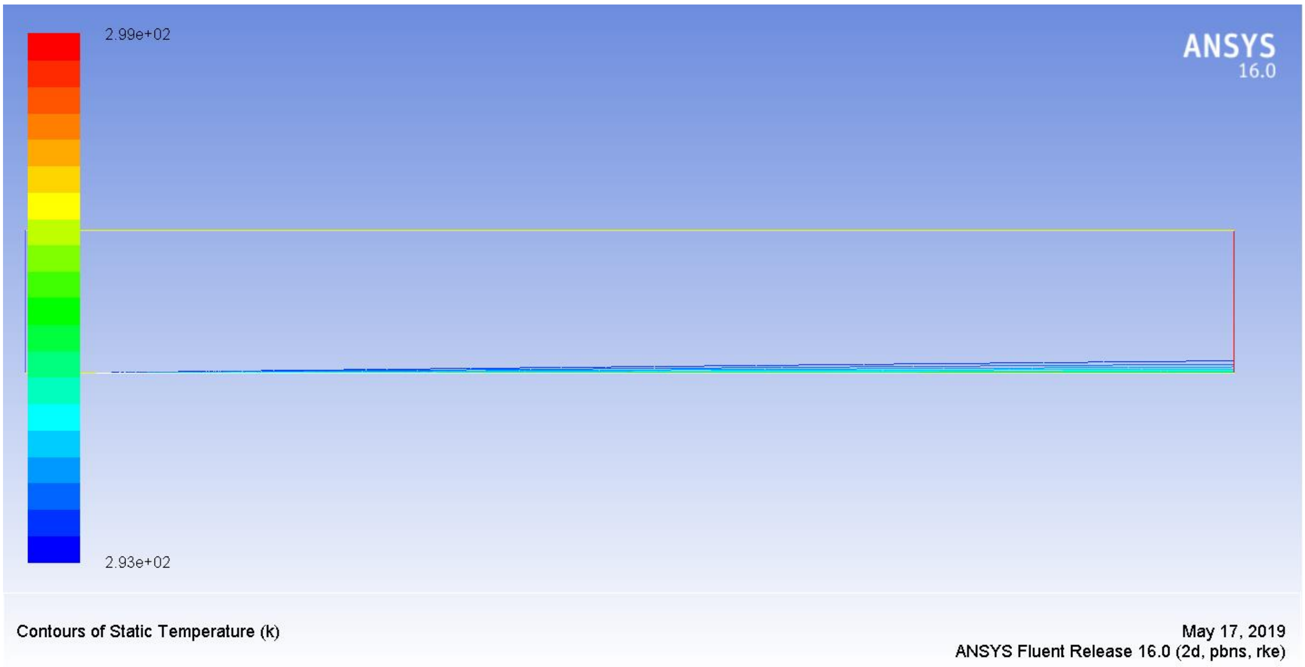


Velocity

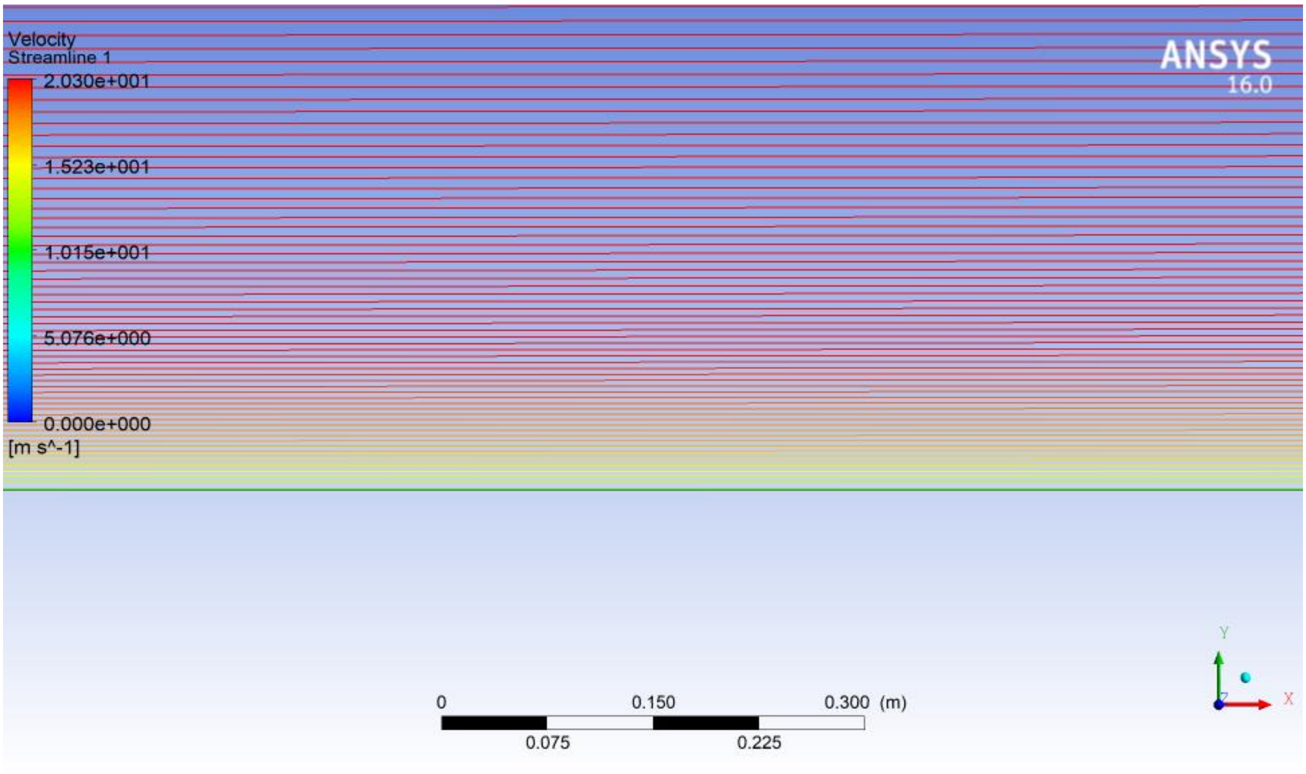


Lines

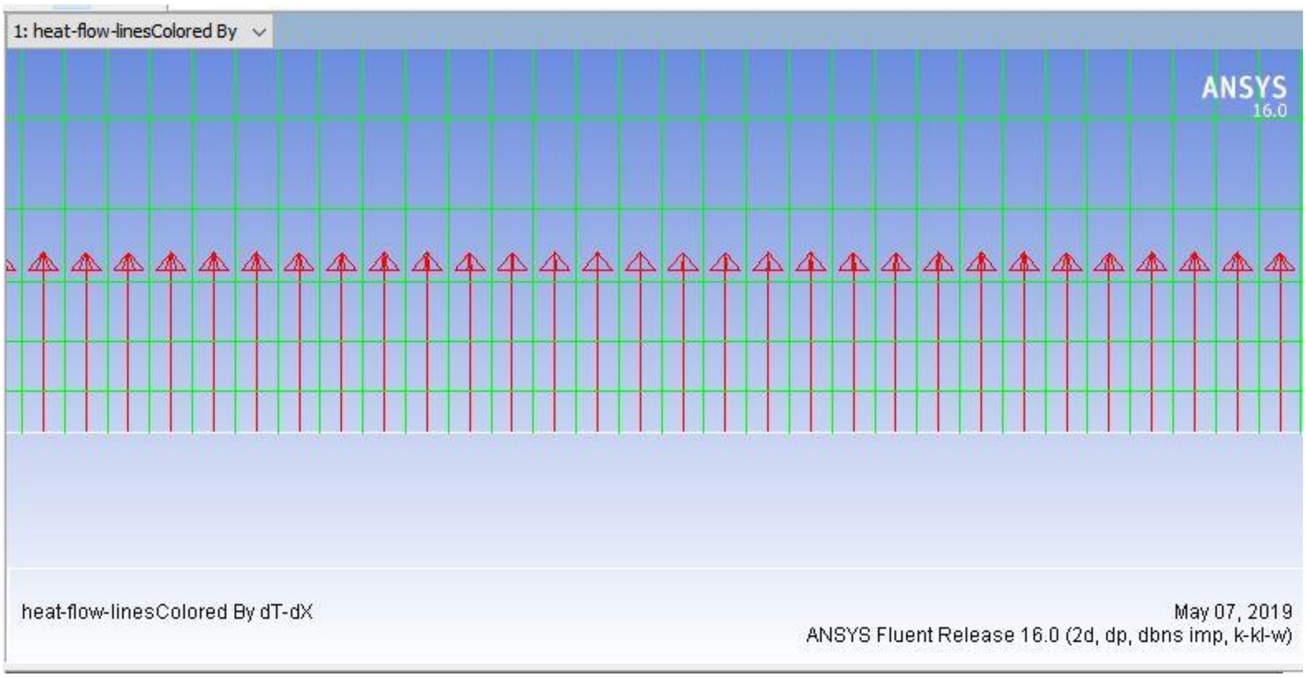
Isotherms



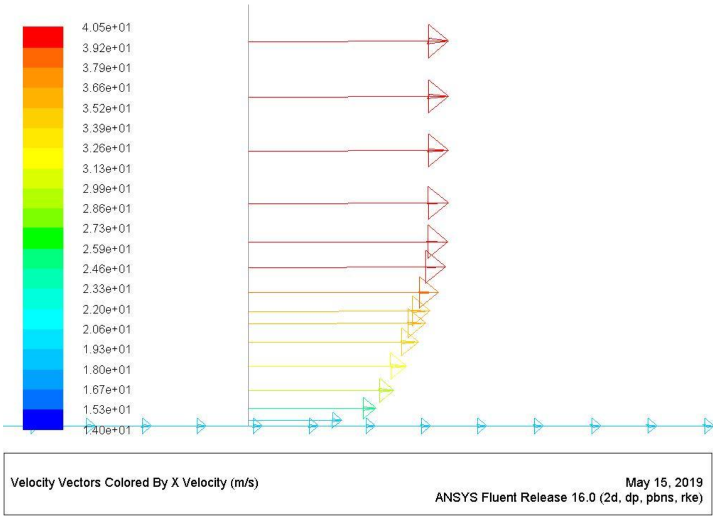
Streamlines



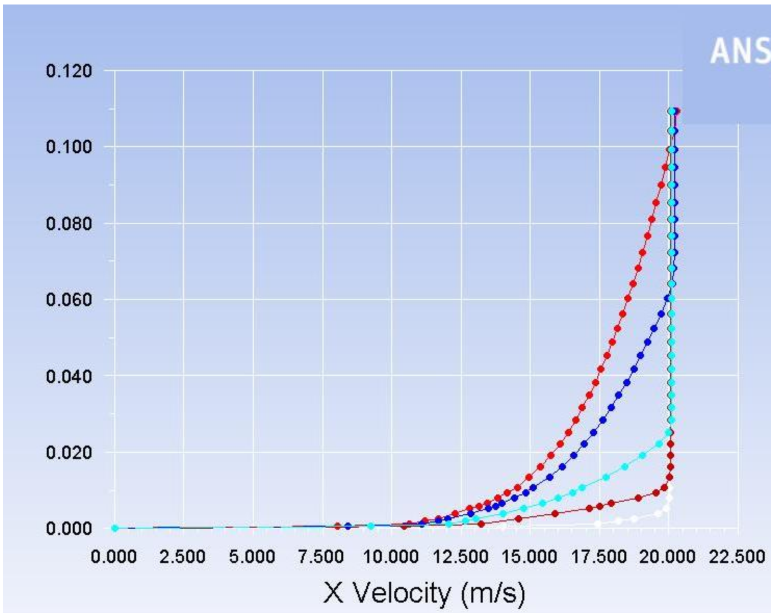
Heat Flow lines



Vectors



Developing Velocity Profile



Enclosure

Description

This problem is modelled as a steady-state, 2-D natural convection problem, taking into consideration body force effects and the variable Density of Fluid with temperature

The study encounters three conditions, 1) vertical enclosure 2) Inclined enclosure 3) Horizontal enclosure (Hot Plate up And Hot Plat down)

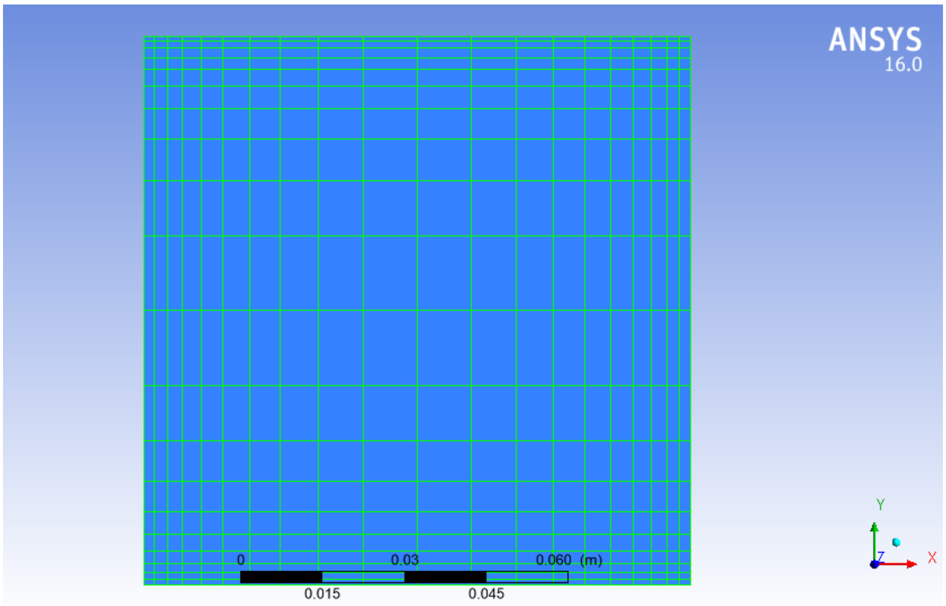
Each one is studied separately

Numerical Calculation

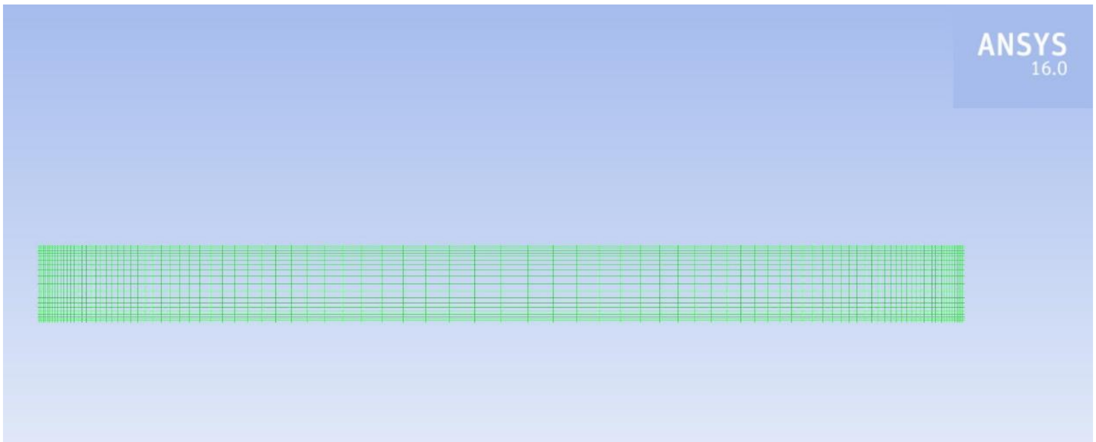
The numerical solution is done on **ANSYS**, using the **COUPLED** solver and the boussinesq approximation for the initial solution to help with convergence.

Mesh:

The edge sizing is applied to get a fine mesh near the edges to capture circulating flow and gradients

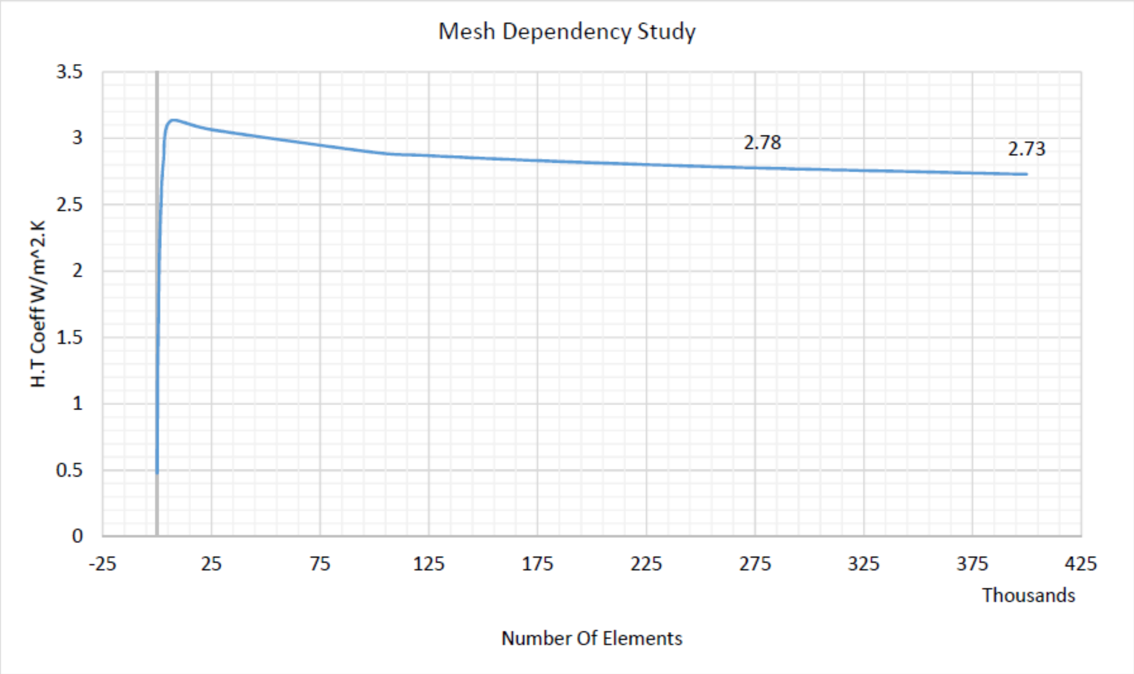


Square enclosure mesh



Rectangular enclosure mesh

Mesh dependency Study



Domain Dependency study

The domain is bounded from all regions so No domain dependency study is needed

Time step dependency Study

The Study is Steady-State So No Time Step dependency is needed

Hand Calculation

The problem is solved by hand using the available correlations [Incropera](9-36 to 9-53)

Equation

Formatted Equations

$$k = \mathbf{k}(Air_{ha}, T=T_{av}, P=P)$$

$$\nu = \frac{\mu}{\rho}$$

$$Pr = \mathbf{Pr}(Air_{ha}, T=T_{av}, P=P)$$

$$Ra = \frac{g \cdot \beta \cdot (T_h - T_c) \cdot \delta^3}{\nu^2} \cdot Pr$$

$$\delta = 0.1$$

$$ratio = \frac{L}{\delta}$$

$$Nus_s = 0.18 \cdot \left[\left(\frac{Pr}{0.2 + Pr} \right) \cdot Ra \right]^{0.29}$$

$$Nus_l = 0.22 \cdot \left[\left(\frac{Pr}{0.2 + Pr} \right) \cdot Ra \right]^{0.28} \cdot ratio^{-0.25}$$

$$Nus_s = \frac{h_s \cdot \delta}{k}$$

$$Nus_l = \frac{h_l \cdot \delta}{k}$$

Formatted Equations

$$Nus_s = \frac{h_s \cdot \delta}{k}$$

$$Nus_l = \frac{h_l \cdot \delta}{k}$$

$$Nus_{l2} = \frac{h_{l2} \cdot \delta}{k}$$

$$Nus_{hor} = \frac{h_{hor} \cdot \delta}{k}$$

$$q = h_{l2} \cdot L \cdot 40$$

$$q_{hor} = h_{hor} \cdot L \cdot 40$$

$$q_{cond} = k \cdot \frac{L}{\delta} \cdot 40$$

$$rt = \frac{q_{hor}}{q}$$

$$Nus_{l2} = 0.046 \cdot Ra^{[1/3]}$$

$$Nus_{hor} = 0.069 \cdot Ra^{[1/3]} \cdot Pr^{0.074}$$

$$Nus_{inc1} = 1 + 1.44 \cdot Star_{term,1} \cdot \left[1 - \frac{1708 \cdot (1.8 \cdot \sin(\theta))^{1.6}}{Ra \cdot \cos(\theta)} \right] + Star_{Term,2}$$

$$Star_{term,1} = 1 - \frac{1708}{Ra \cdot \cos(\theta)}$$

$$Star_{Term,2} = \frac{(Ra \cdot \cos(\theta))^{(1/3)}}{18} - 1$$

$$Nus_{aboveThetaCr} = Nus_{l2} \cdot \sin^{0.25}(\theta)$$

Results

Relation between L and Q

Q1 from first Correlation And Q2 From Second Correlation

	Analytical		Numerical		Analytical		Numerical
L	Q1	Q2	Q	L	Q1	Q2	Q
0.1	14.528	7.768	-15.4967	-	-	-	-
0.2	29.056	15.536	-28.01	2.2	155.056	170.896	-259
0.4	43.168	31.072	-49.996	2.4	165.504	186.432	-284
0.6	58.512	46.608	-70.4648	2.6	175.76	201.968	-309.65
0.8	72.608	62.144	-91.3546	2.8	185.808	217.504	-333
1	85.84	77.68	-113	3	195.6	233.04	-358
1.2	98.4	93.216	-138.87	3.2	205.312	248.576	-382
1.4	110.488	108.752	-163	3.4	214.88	264.112	-406
1.6	122.112	124.288	-187.3	3.6	224.352	279.648	-431
1.8	133.416	139.824	-211	3.8	233.624	295.184	-455
2	144.32	155.36	-235	4	242.72	310.72	-479

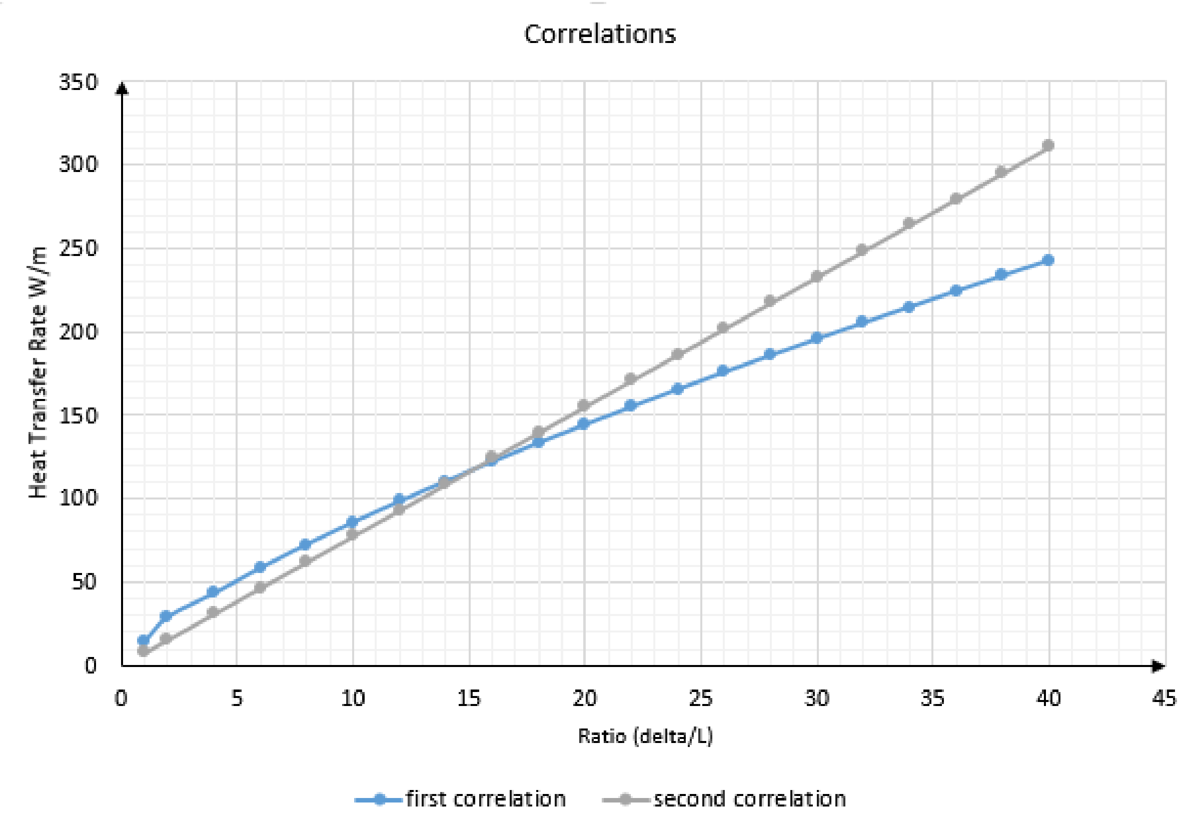
Relation between Theta and Heat Transfer Rate at Length = 1.2m

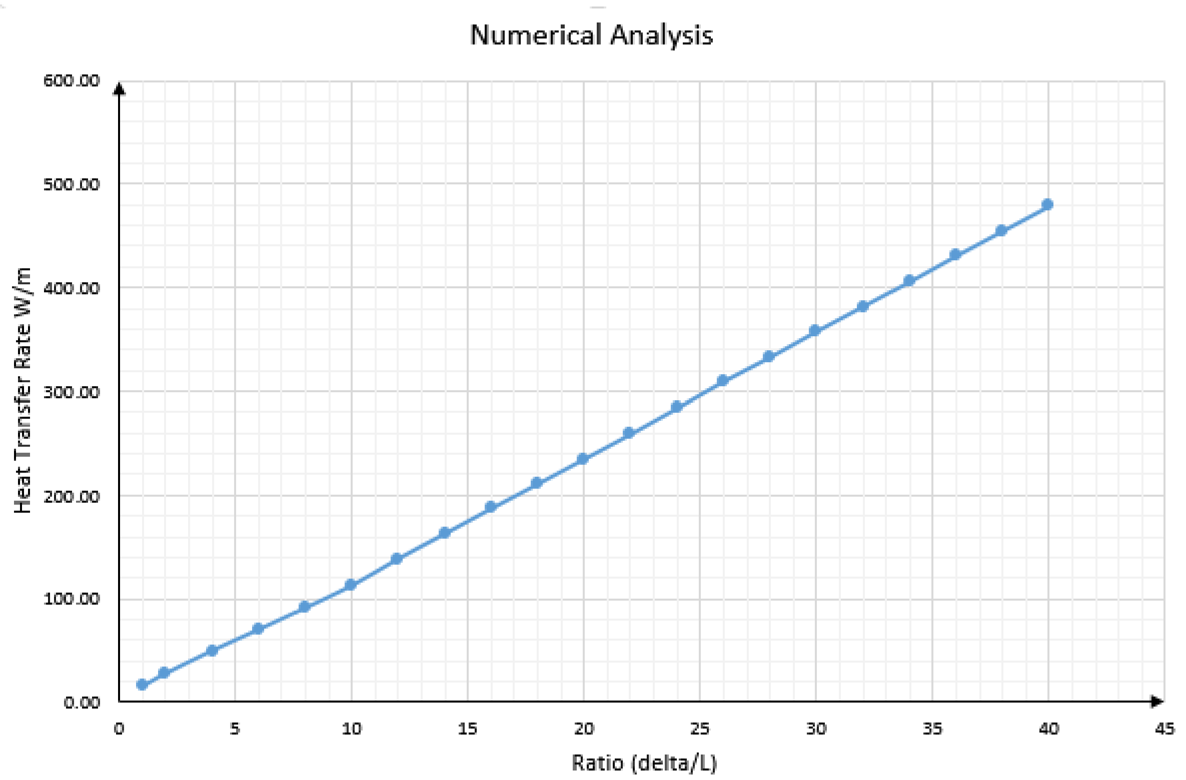
Theta	Q Numerical	Q Analytical	Theta	Q Numerical	Q Analytical
0.000	161.369	129.360	-	-	-
10.000	152.830	127.584	100.000	141.586	-
20.000	152.640	124.656	110.000	136.114	-
30.000	149.964	120.336	120.000	128.963	-
40.000	150.107	114.480	130.000	120.024	-
50.000	150.814	106.656	140.000	109.191	-
60.000	151.029	96.000	150.000	95.751	-
70.000	150.348	80.016	160.000	78.020	-
80.000	148.629	93.216	170.000	49.990	-
90.000	145.724	-	180.000	11.600	11.600

Undefined Values for Analytical solution due to absence of suitable Correlation for an inclined enclosure with hot plat up

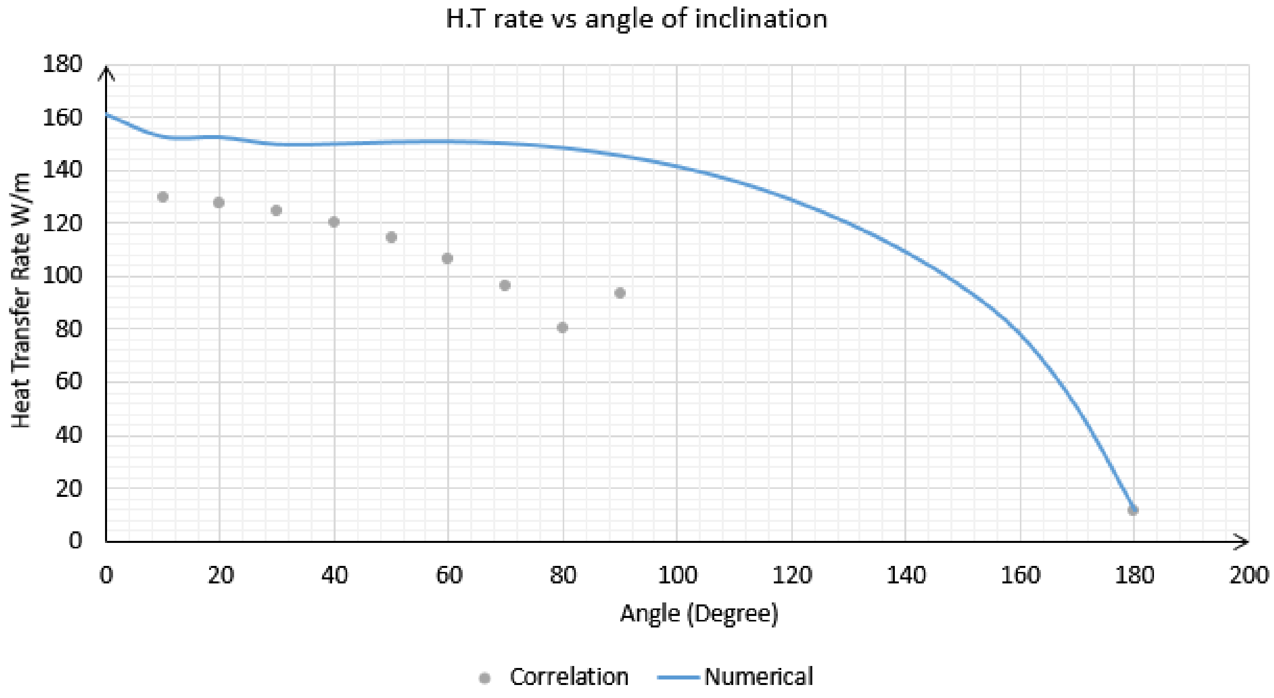
Plots

Required





It is observed that the solution can be considered as a superposition between the results of both correlation and the result conforms with both

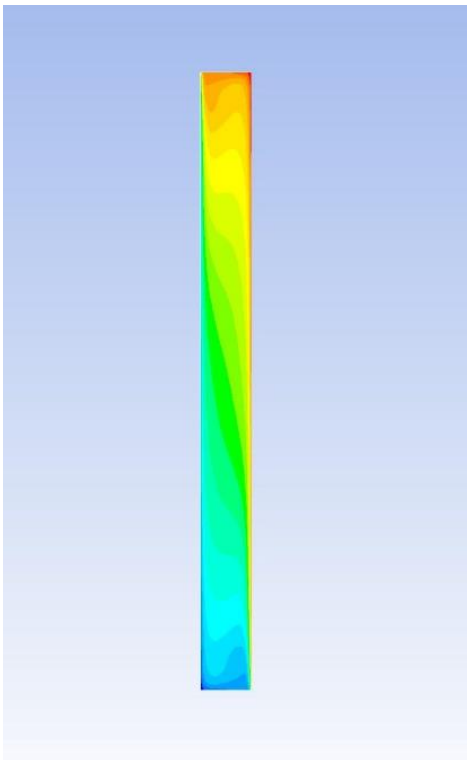


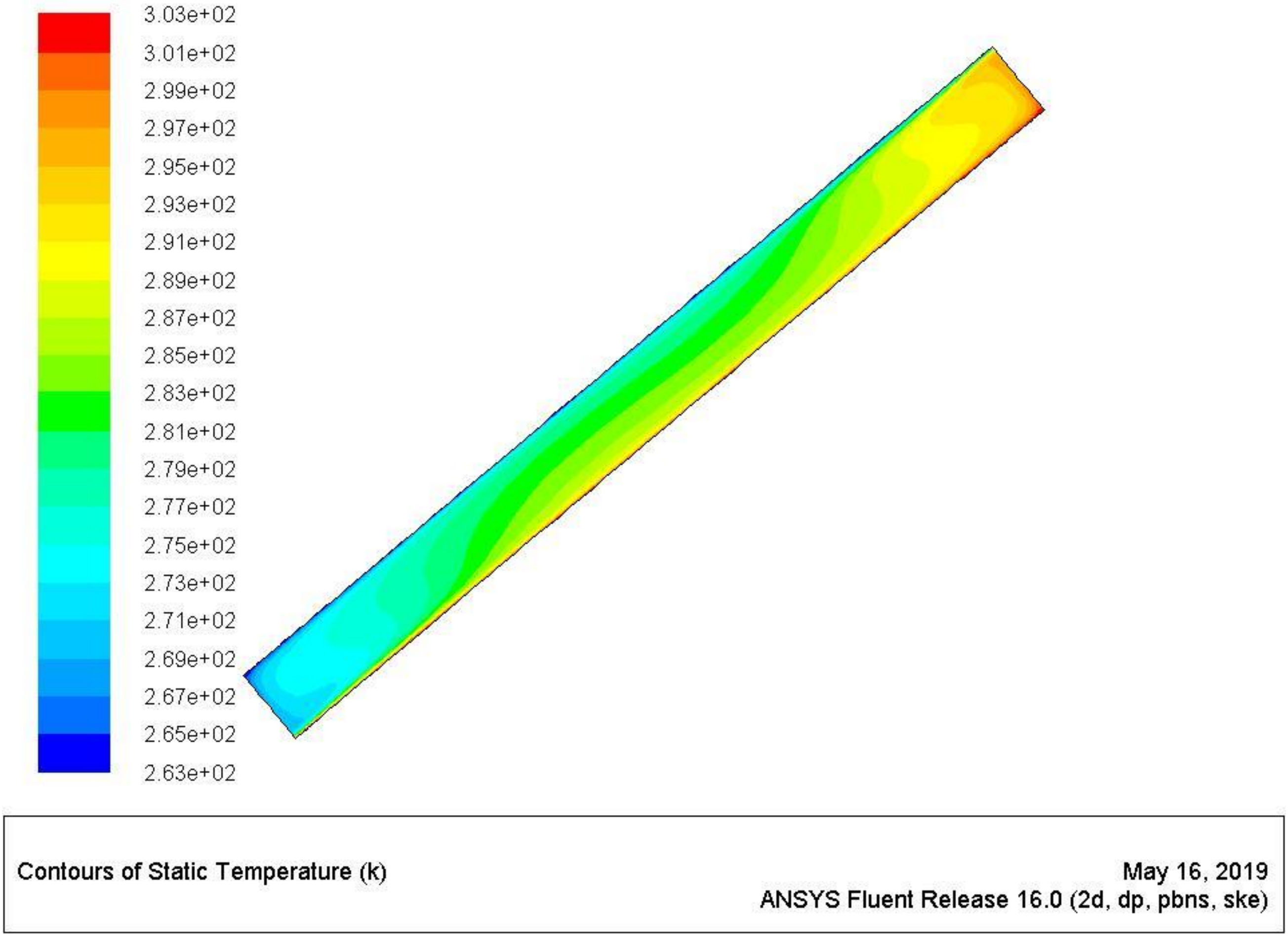
Graphics

Contours

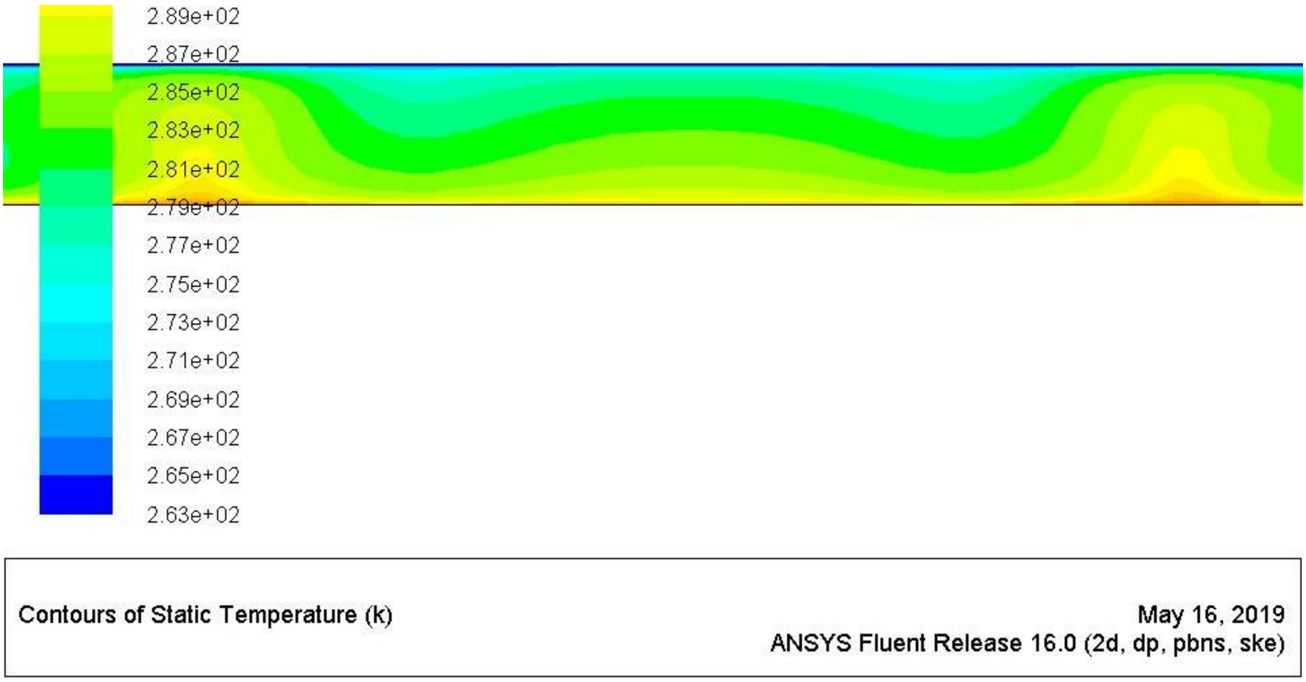
Temperature

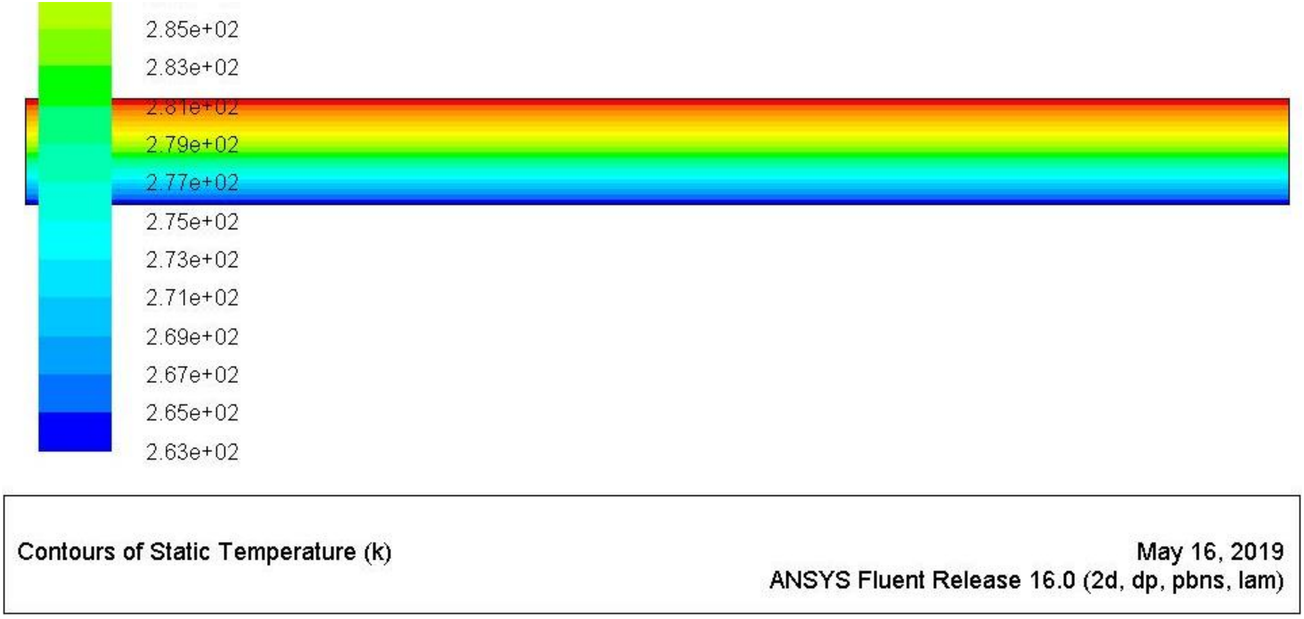
Vertical and inclined




3.03e+02
3.01e+02
2.99e+02
2.97e+02
2.95e+02
2.93e+02
2.91e+02
2.89e+02
2.87e+02
2.85e+02
2.83e+02
2.81e+02
2.79e+02
2.77e+02
2.75e+02
2.73e+02
2.71e+02
2.69e+02
2.67e+02
2.65e+02
2.63e+02
Contours of Static Temperature (k)
May 16, 2019
ANSYS Fluent Release 16.0 (2d, dp, pbns, ske)

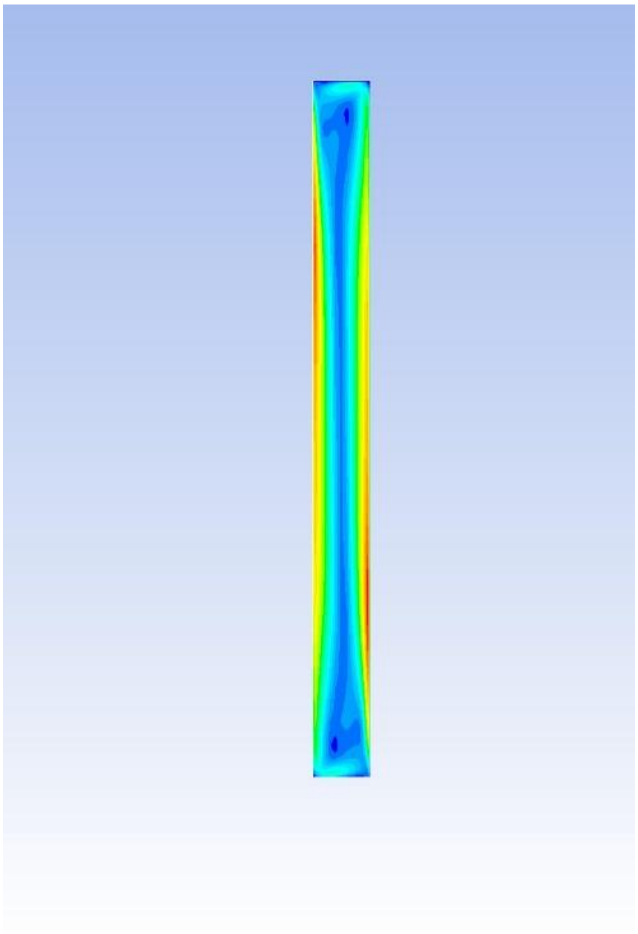
Horizontal

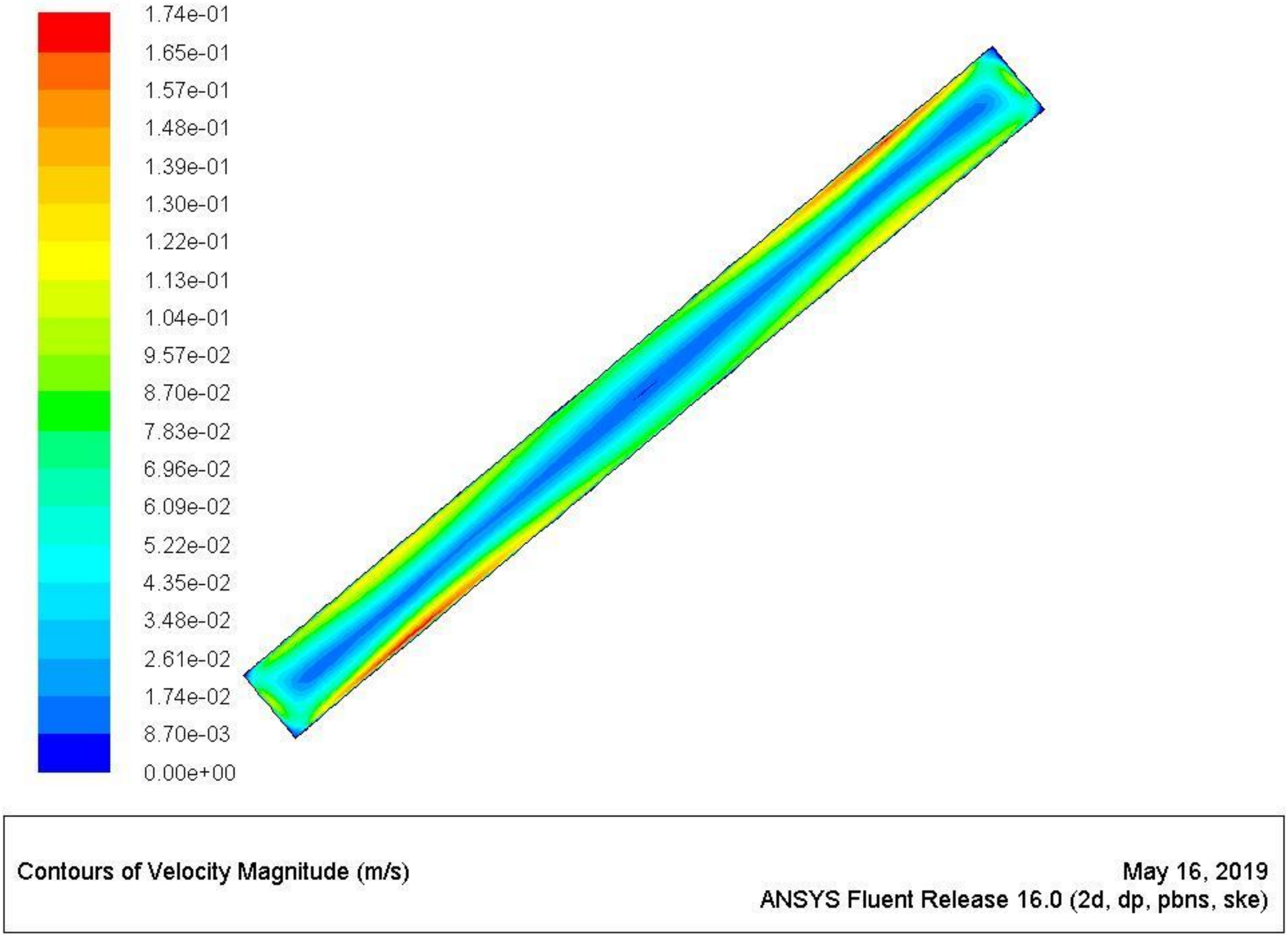

2.89e+02
2.87e+02
2.85e+02
2.83e+02
2.81e+02
2.79e+02
2.77e+02
2.75e+02
2.73e+02
2.71e+02
2.69e+02
2.67e+02
2.65e+02
2.63e+02
Contours of Static Temperature (k)
May 16, 2019
ANSYS Fluent Release 16.0 (2d, dp, pbns, ske)



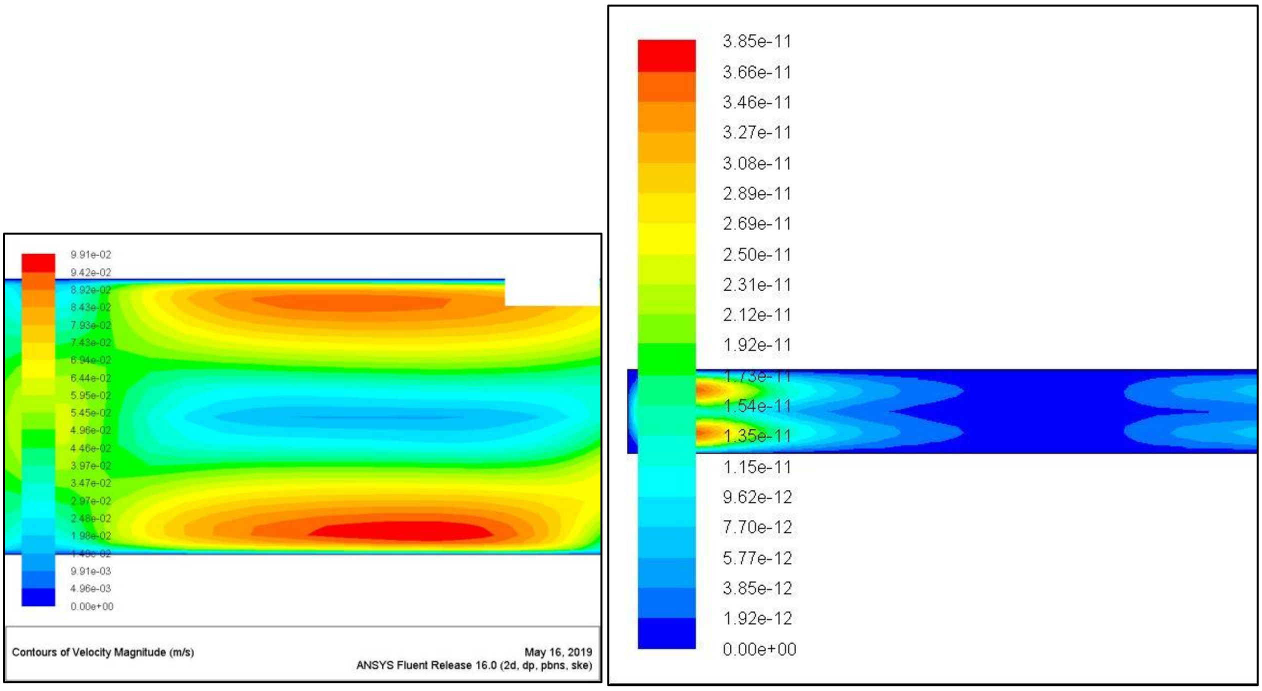
Velocity

Vertical And Inclined





Horizontal

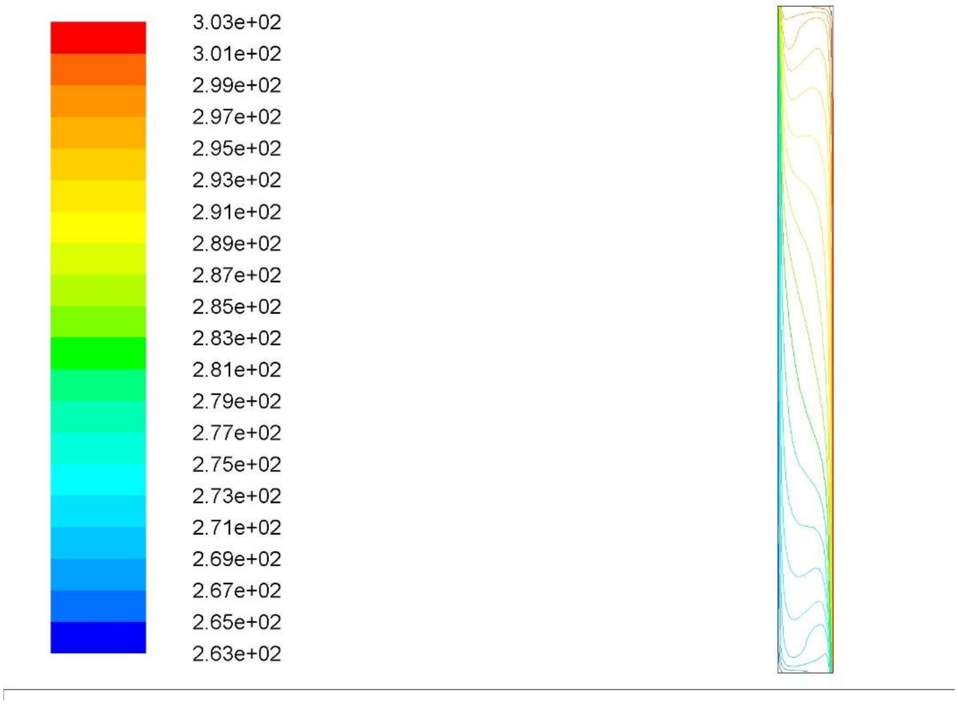


Rotational flow for hot plate down (left) and stagnant for hot plate up (right)

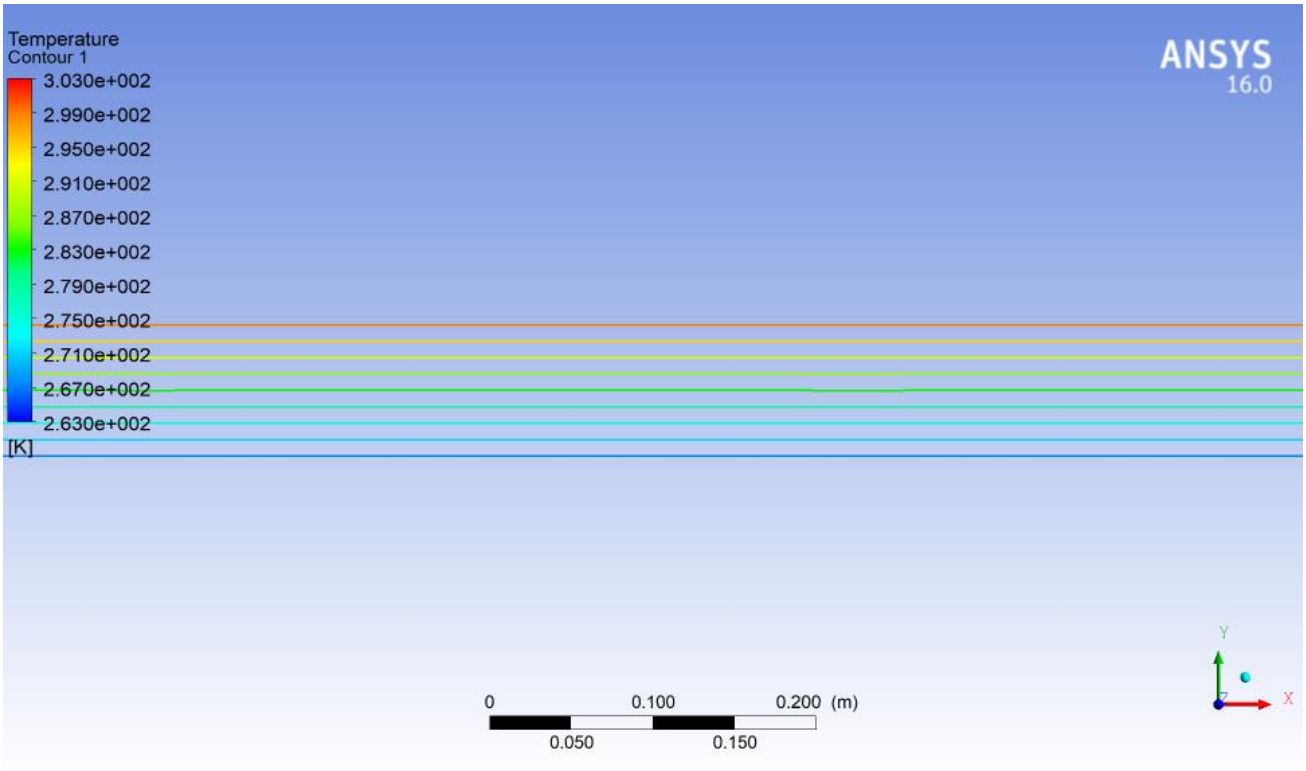
Lines

Isotherms

Vertical

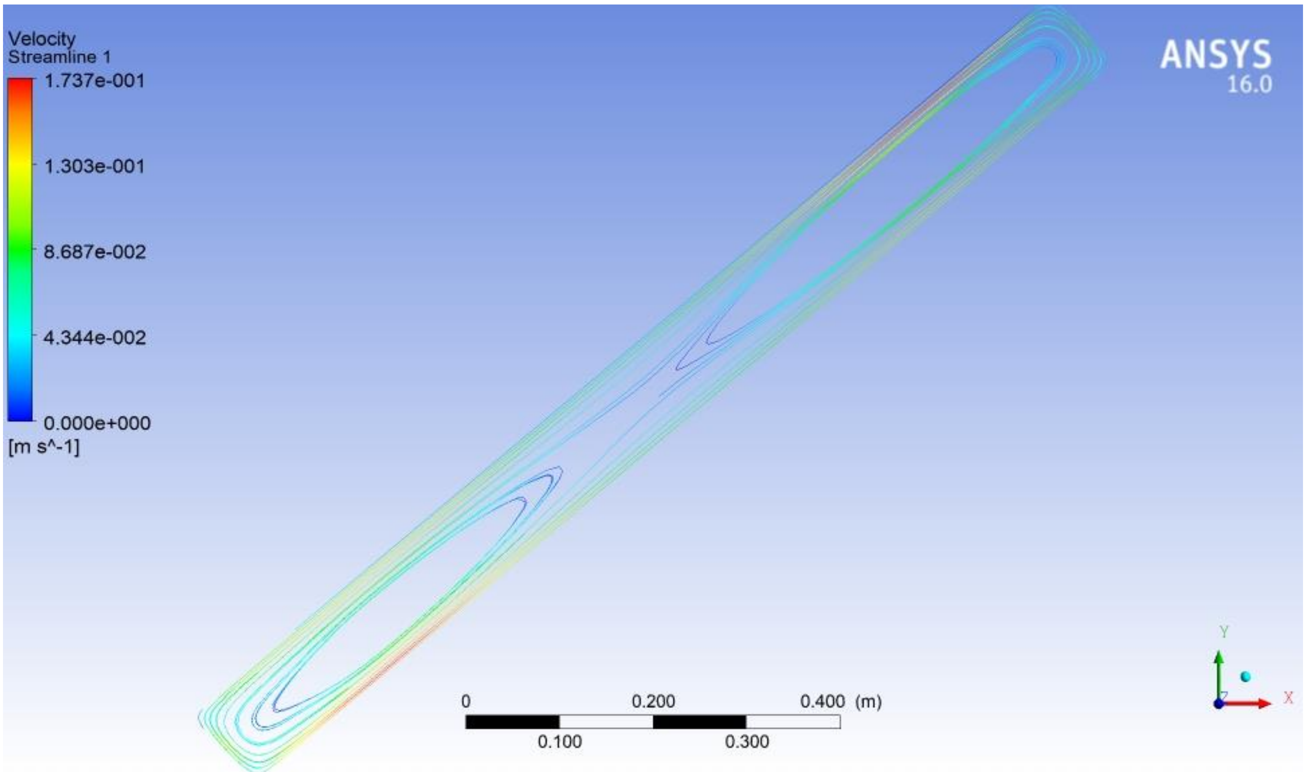


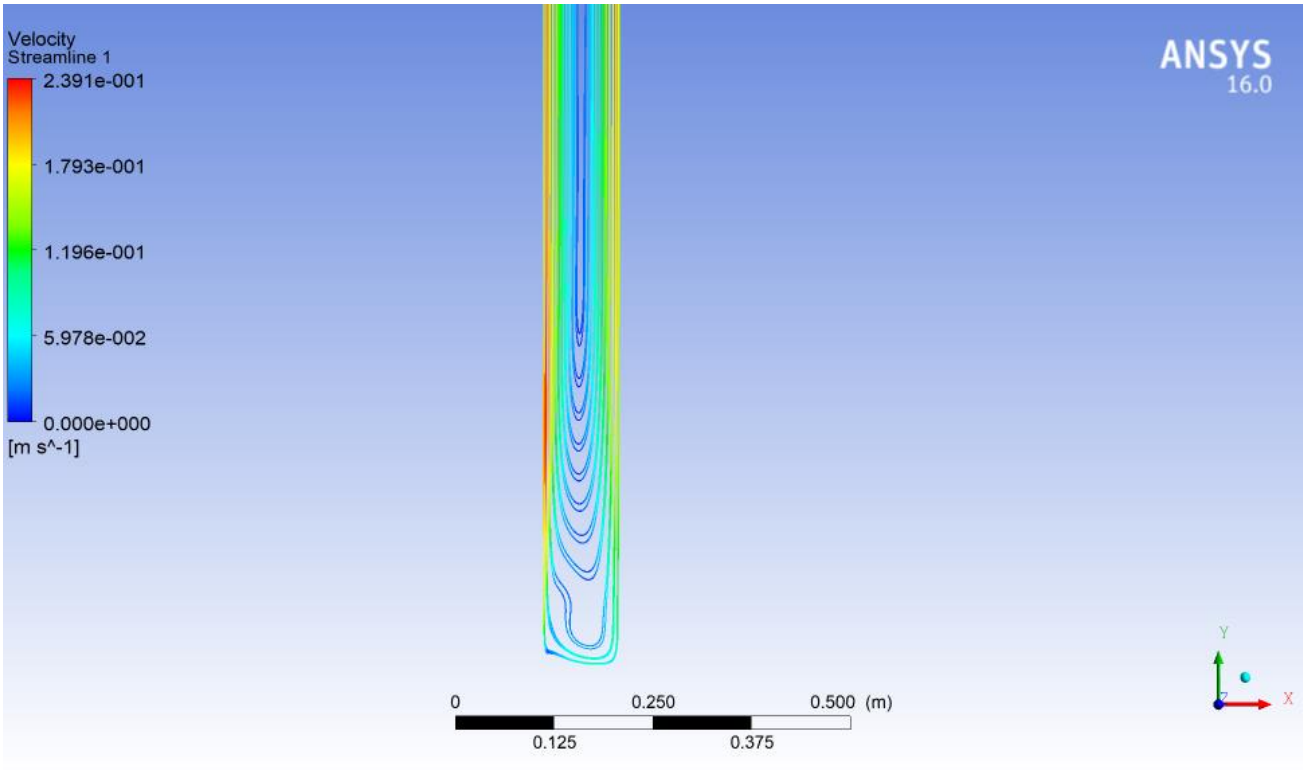
Horizontal (Hot plate up)



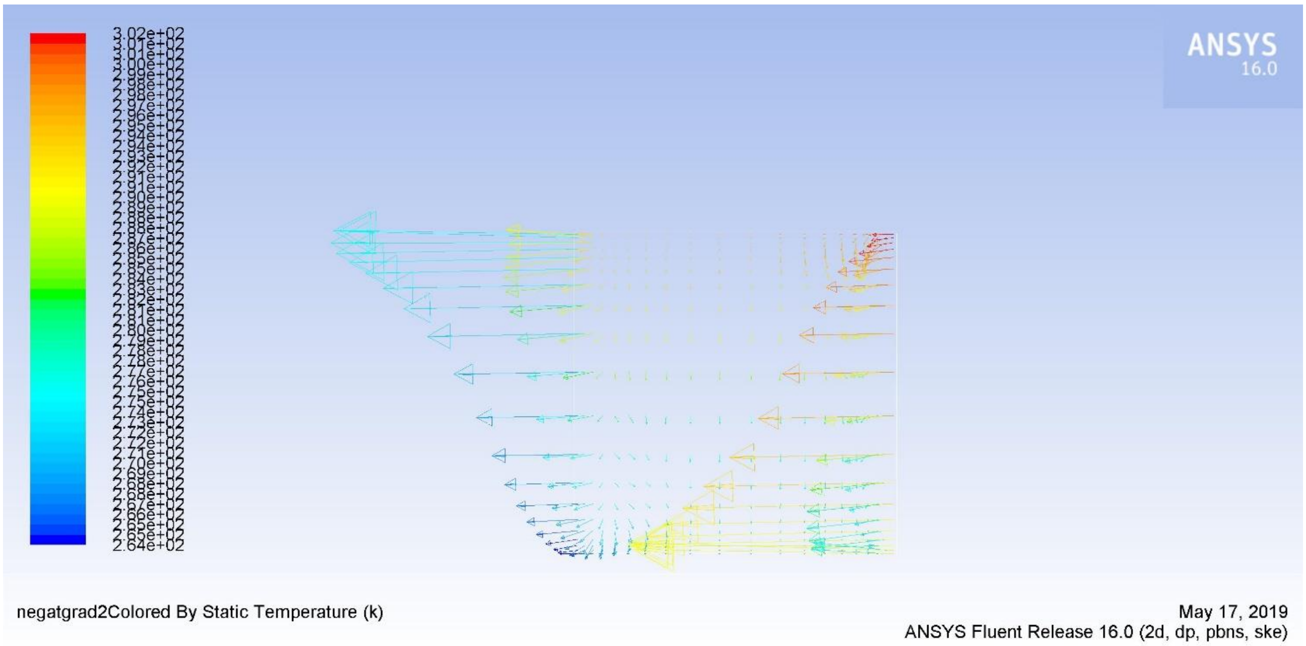
Streamlines

Inclined and vertical

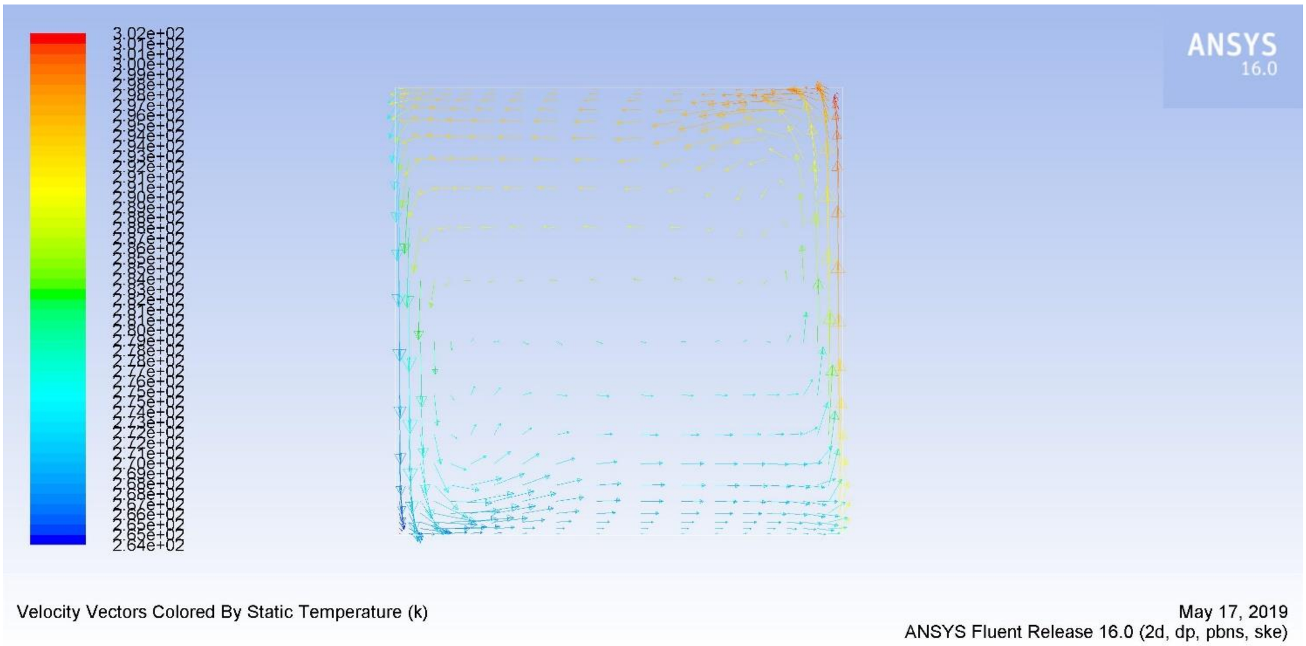


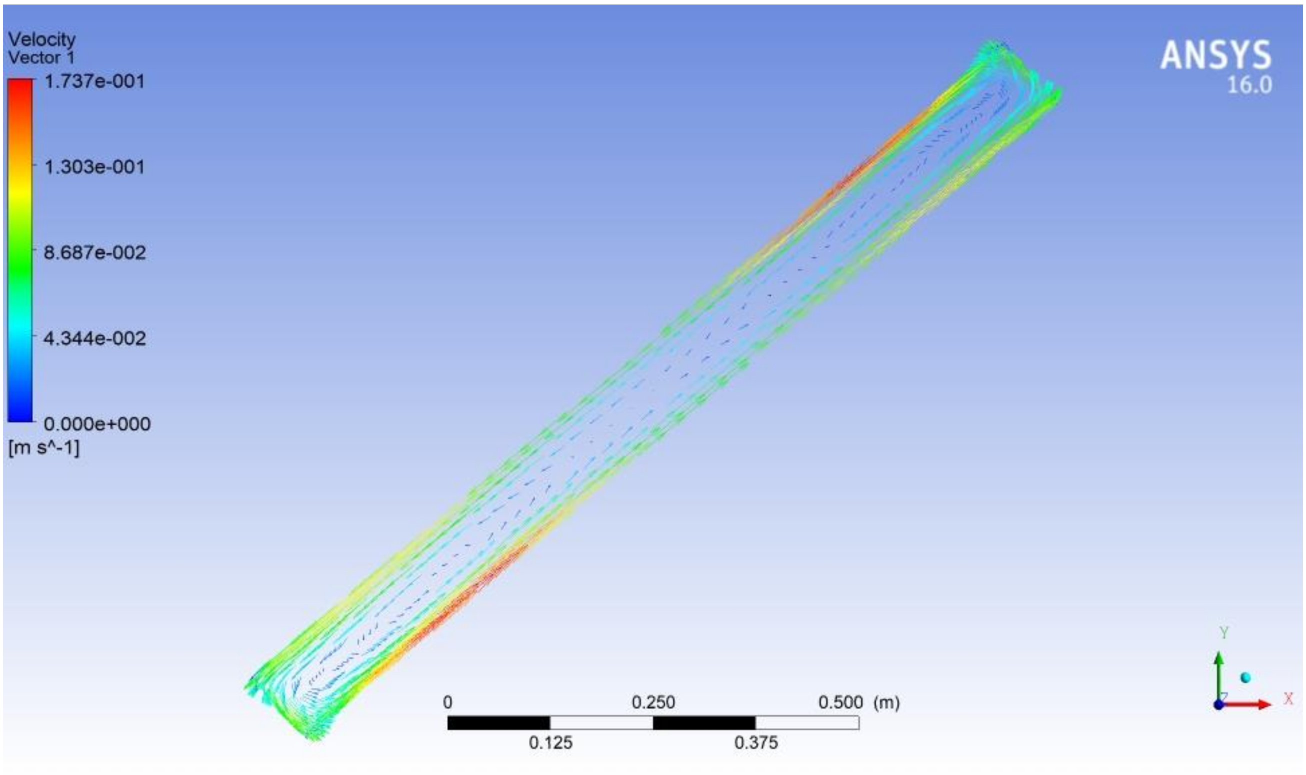


Heat Flow lines



Vectors





Egg

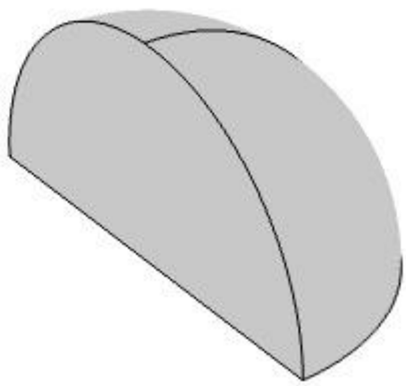
Description

The problem is modelled as 3-D Transient conduction In A sphere

Numerical Calculation

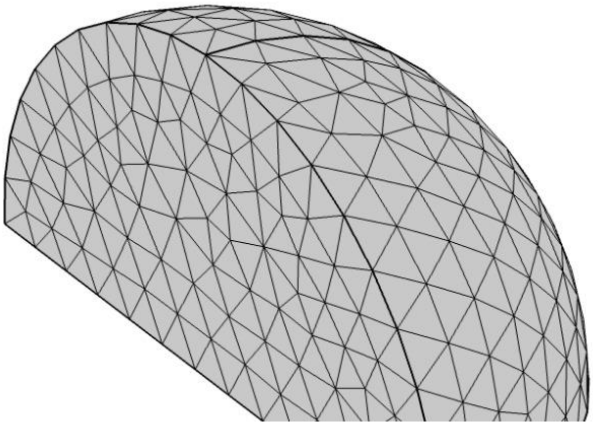
Geometry

Only Half a sphere is modelled since it is axisymmetric to save computational cost



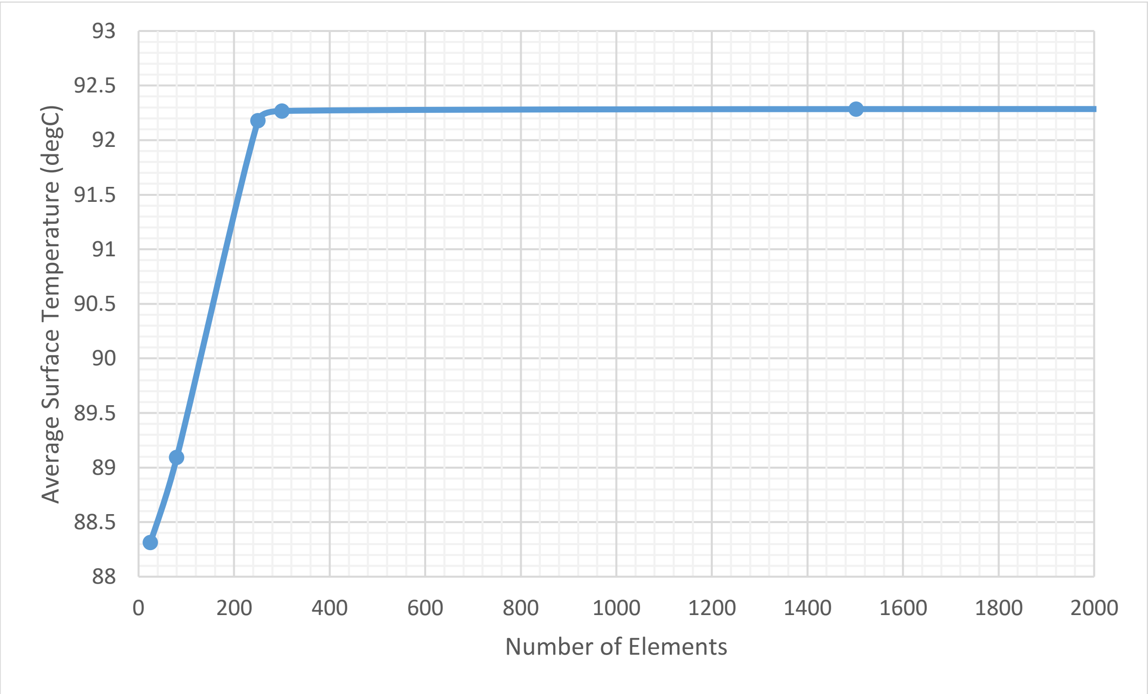
Mesh:

A physics controlled, auto generated hex mesh is used.

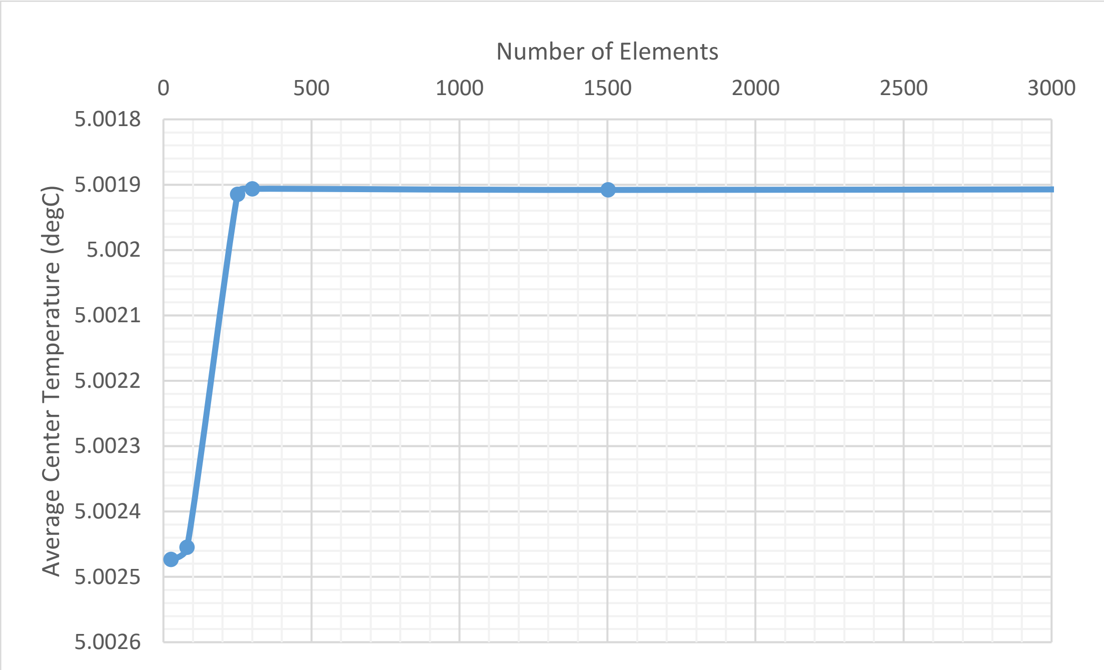


Mesh dependency Study

Surface Temperature



Centre Temp:

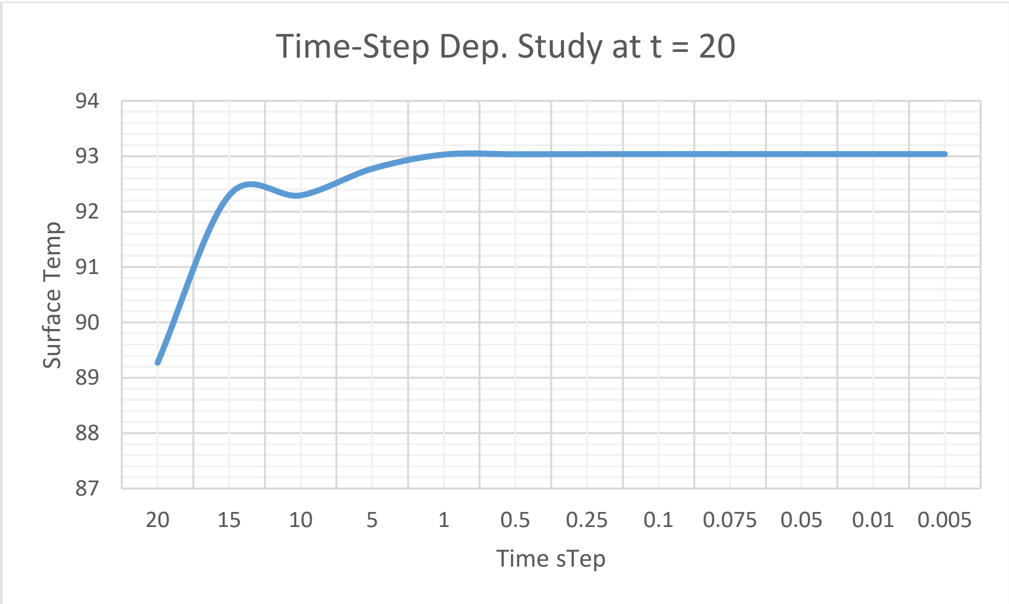


It Is noticed that the results are hardly dependent of the mesh as in converges after a relatively coarse mesh

Domain Dependency study

The domain is Bounded So No Domain Dep Study is needed

Time step dependency Study



It IS observed that the solution is highly affected by the solver time step, but it converges after a time step of approximately 0.1 s

Hand Calculation

Equations

Formatted Equations

$$Bi = \frac{h \cdot L_c}{K}$$

$$L_c = R$$

$$R = \frac{D}{2}$$

$$D = 0.05 \quad [m]$$

$$h = 3000$$

$$\lambda = 3.12$$

$$A = 2$$

$$\frac{T - T_{inf}}{T_i - T_{inf}} = A \cdot \mathbf{exp}\left(-\lambda^2 \cdot \tau\right)$$

$$\frac{T_s - T_{inf}}{T_i - T_{inf}} = A \cdot \mathbf{exp}\left(-\lambda^2 \cdot \tau\right) \cdot \frac{\mathbf{cos}\left[\lambda \cdot \frac{360}{3.14}\right]}{\lambda}$$

$$\tau = \frac{\alpha \cdot time}{L_c^2}$$

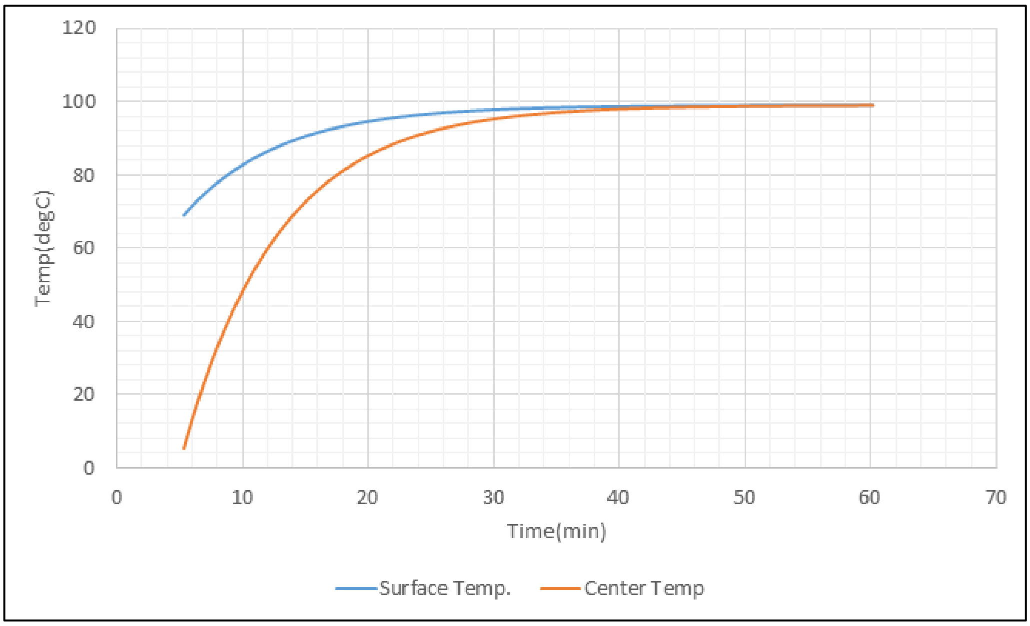
Results

	Analytical		Numerical	
Time(min)	T_Center	T_surface	T_Center	T_surface
2	52.65	-45.72	5.143692	97.15074
3	58.34	-27.97	6.444813	97.68472
4	63.32	-12.4	7.979248	97.84508
5	67.7	1.262	13.04192	98.08995
6	71.54	13.25	20.17801	98.25875
8	77.86	32.99	36.15454	98.49288
11	84.72	54.42	51.52901	98.63643
13	88.01	64.68	64.15955	98.73304
15	90.54	72.58	73.69571	98.80272
19	93.99	83.35	83.27381	98.87487
22	95.61	88.43	89.26541	98.92163
25	96.71	91.86	92.9771	98.95134
29	97.65	94.77	95.27554	98.96994
32	98.08	96.14	96.69971	98.98148
35	98.38	97.07	97.58144	98.9886

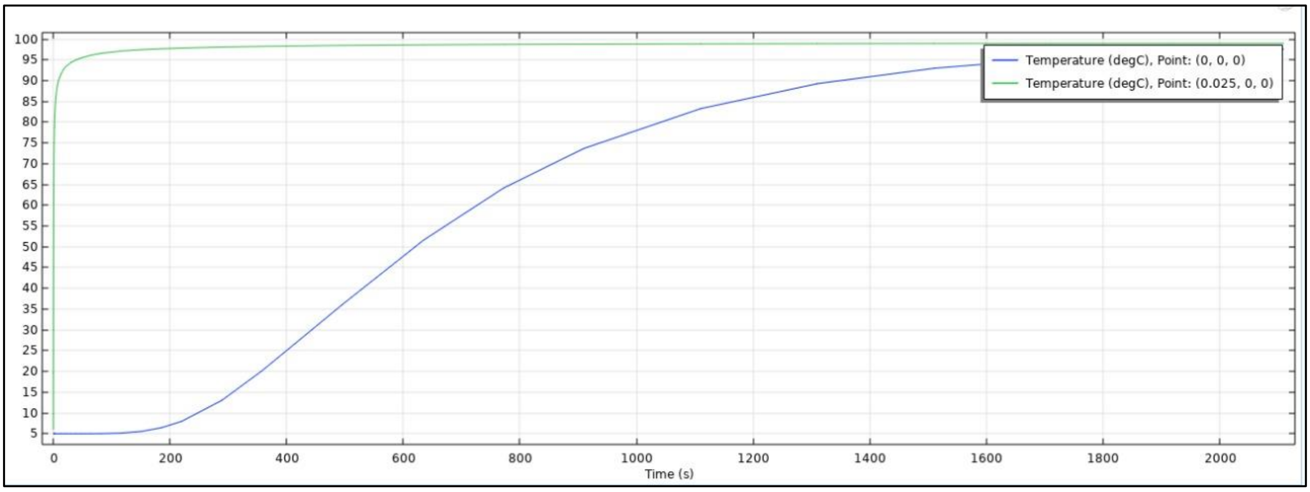
Plots

Required

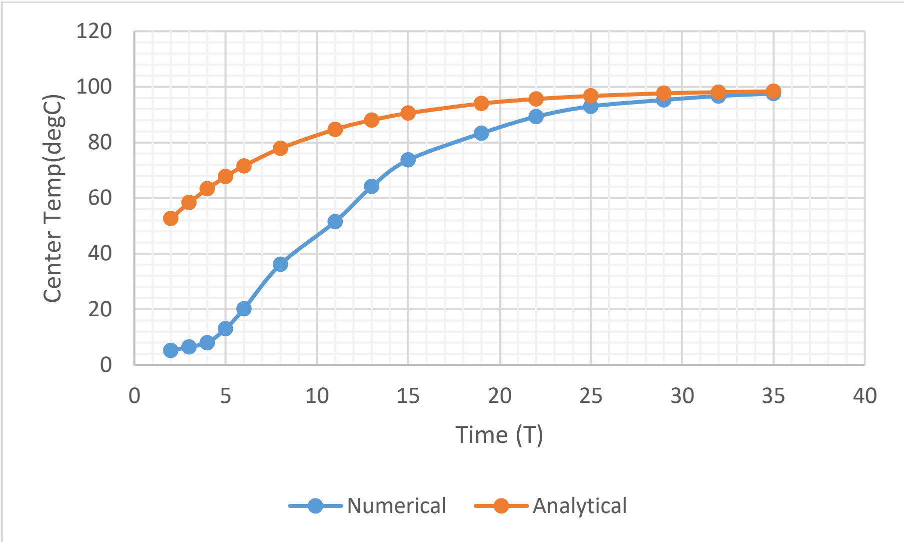
Analytical

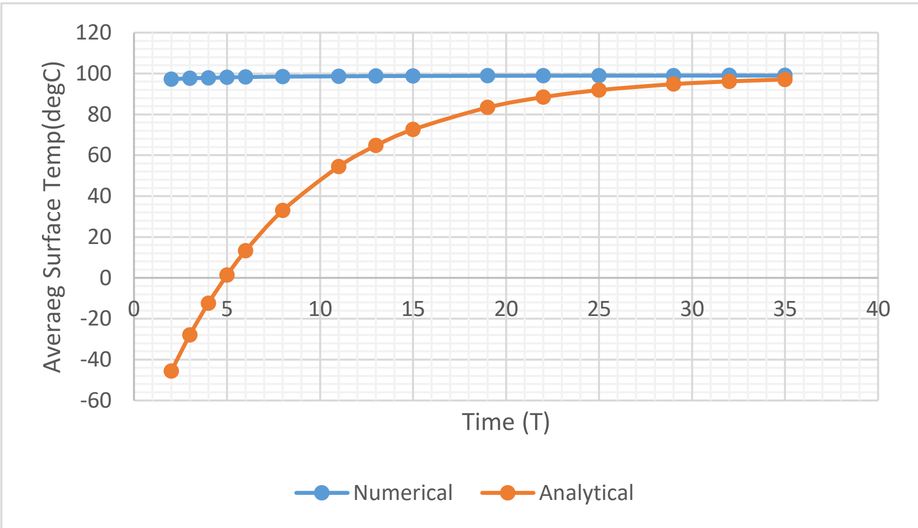


Numerical



Comparison



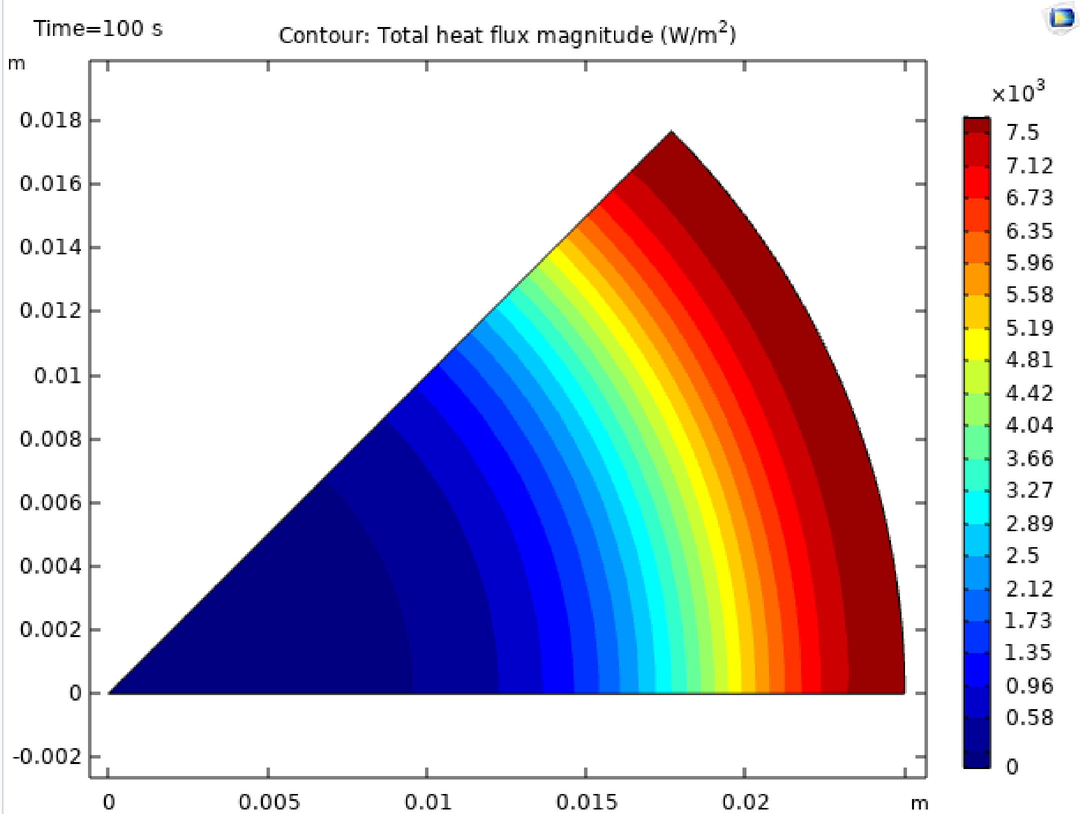


There is great Error at small time values in the analytical solution due to the One-Term Approximation of the fourrier expansion used to solve the model, but the time taken to reach maximum temperature is approximatley the same.

Graphics

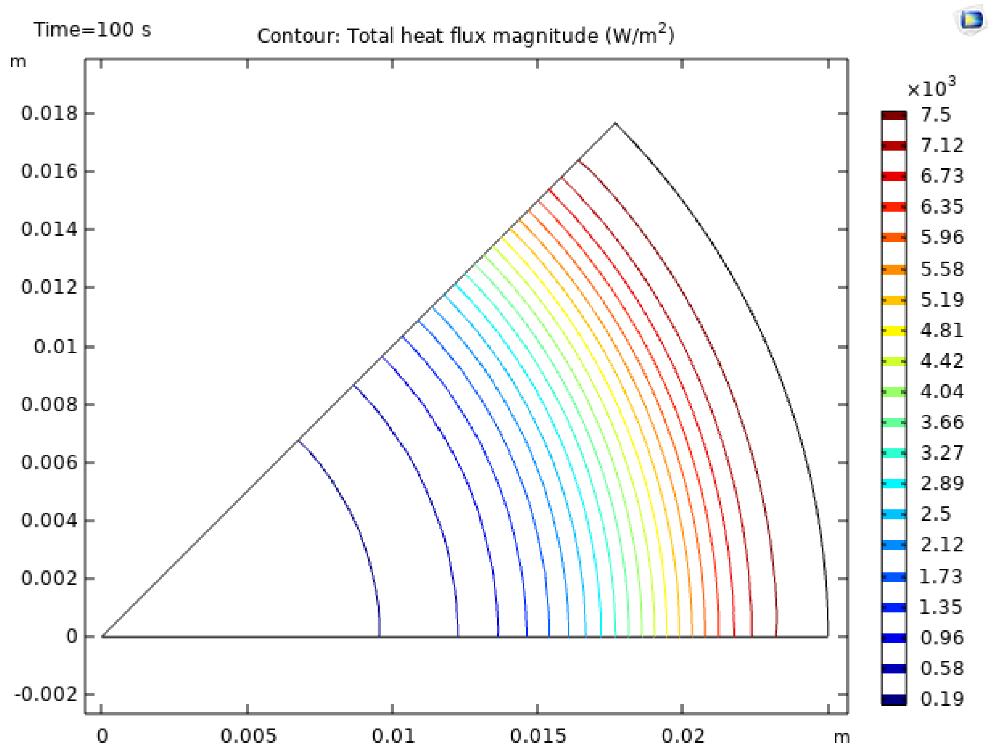
Contours

Temperature



Lines

Isotherms



Heat Flow lines