Problem 1 – 1

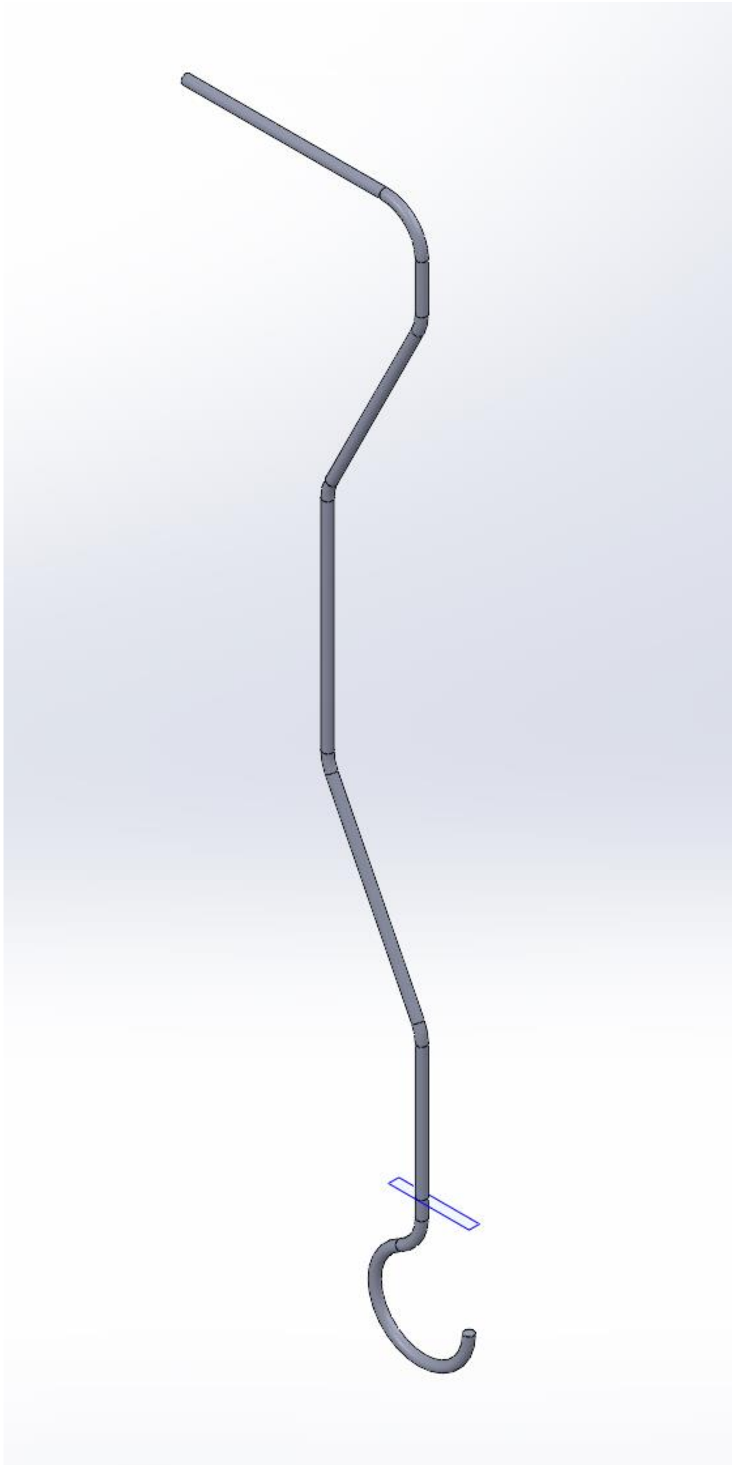


Figure 1-1: CAD Model of removal tool/hook

Problem 1 – 2

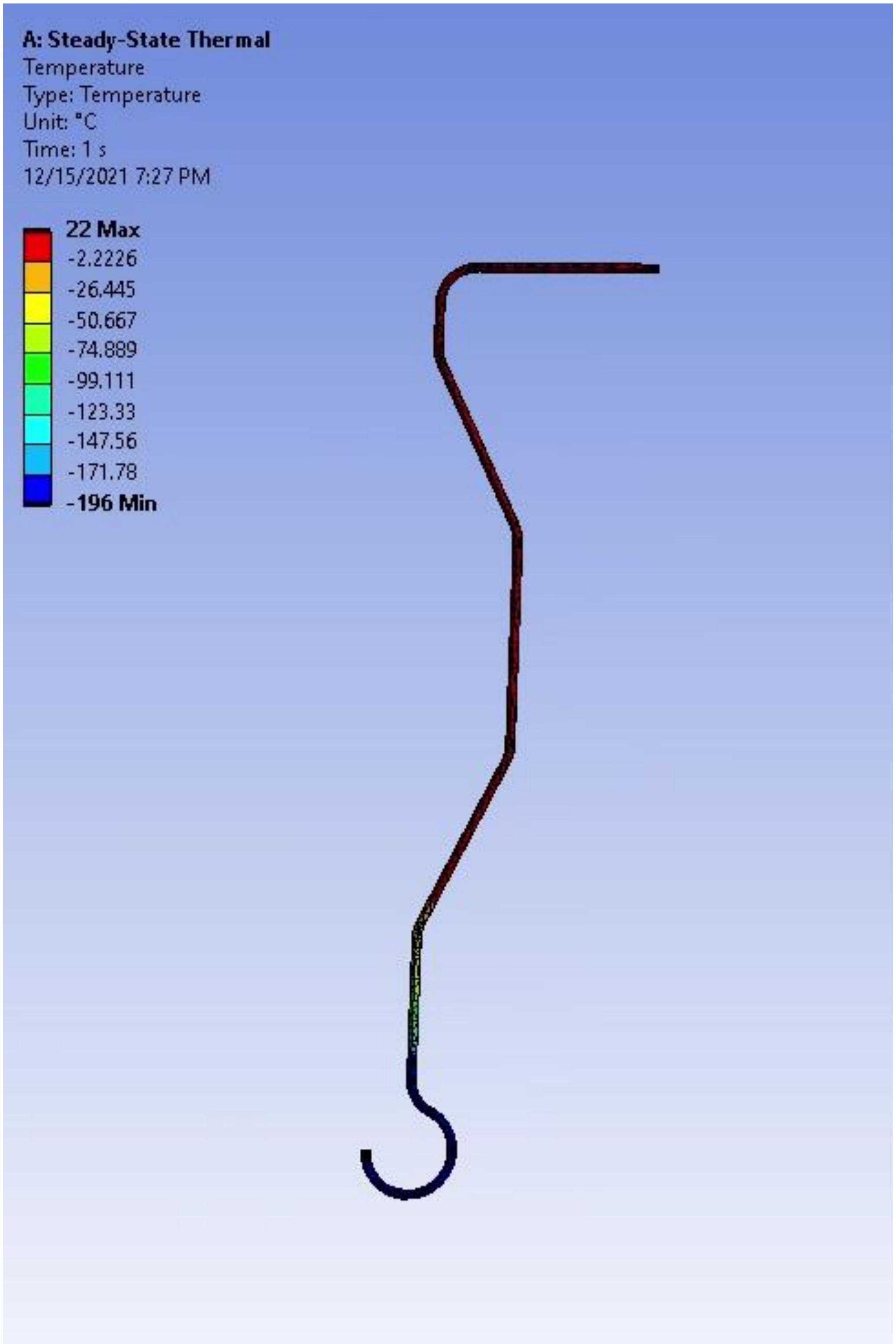


FIGURE 1-2-1: Temperature Contour Plot of the Entire tool before convergence study is performed.

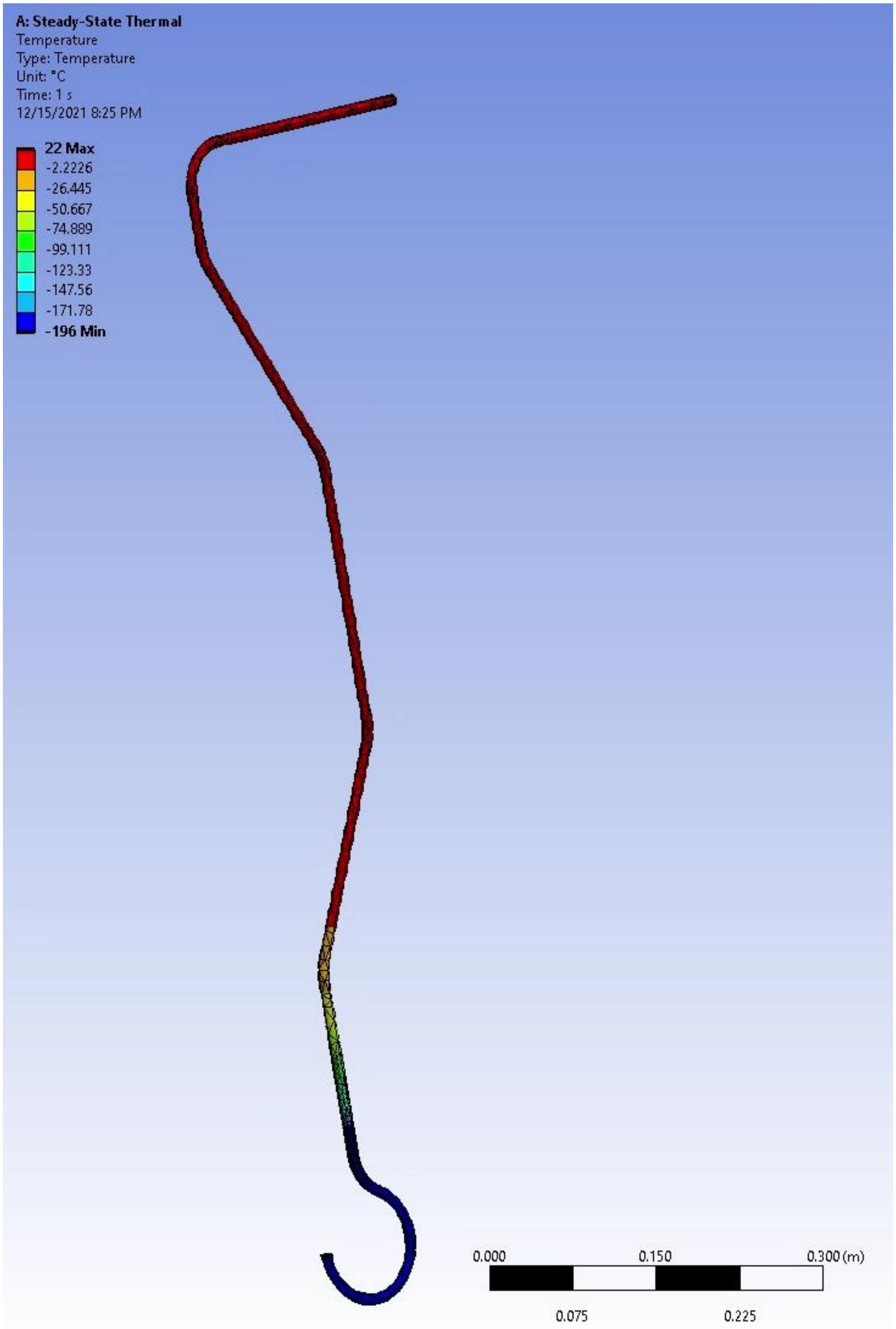


FIGURE 1-2-2: Temperature Contour Plot of the Entire tool after convergence study is performed.

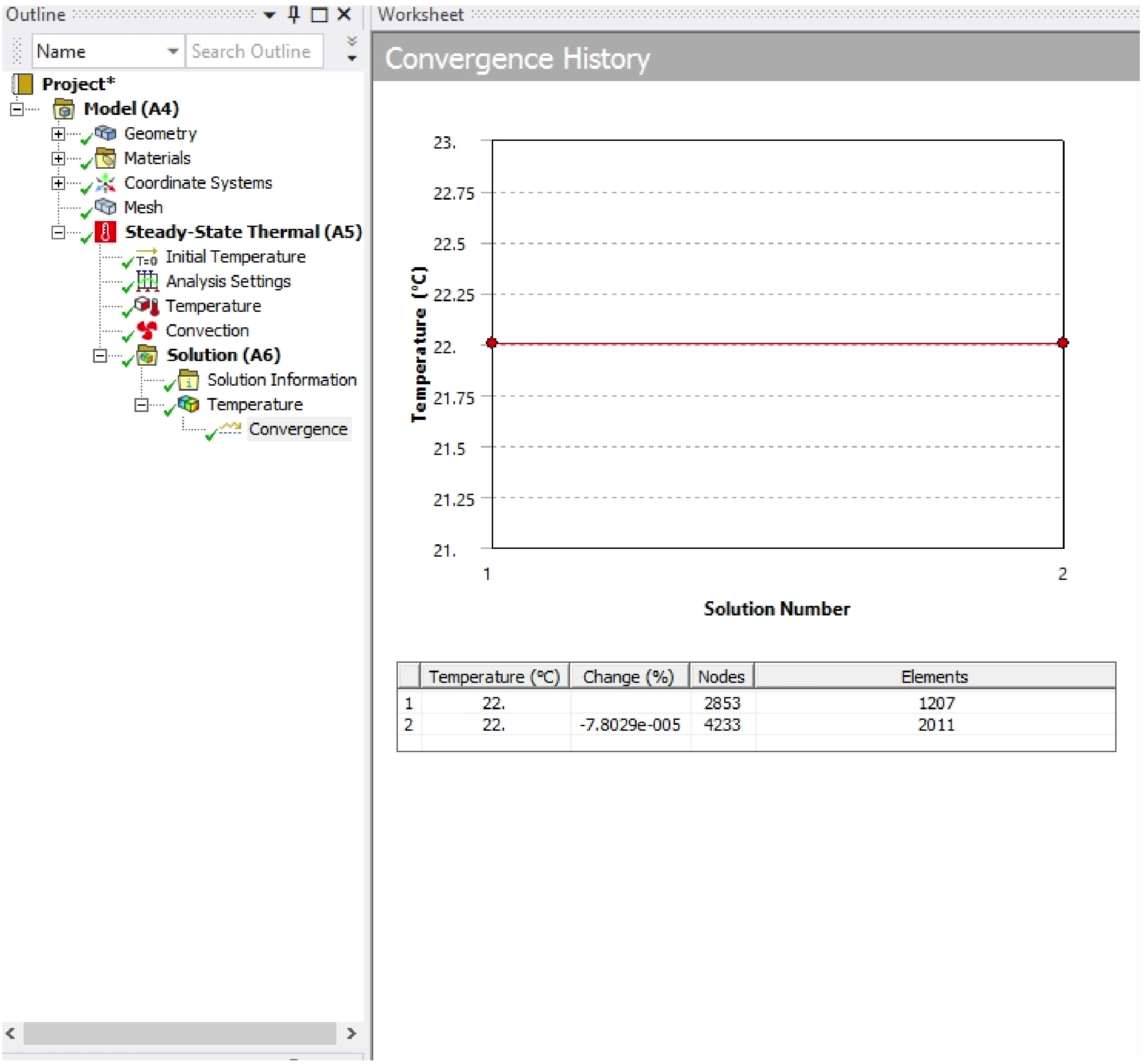


FIGURE 1-2-2-1: Convergence study data for verification

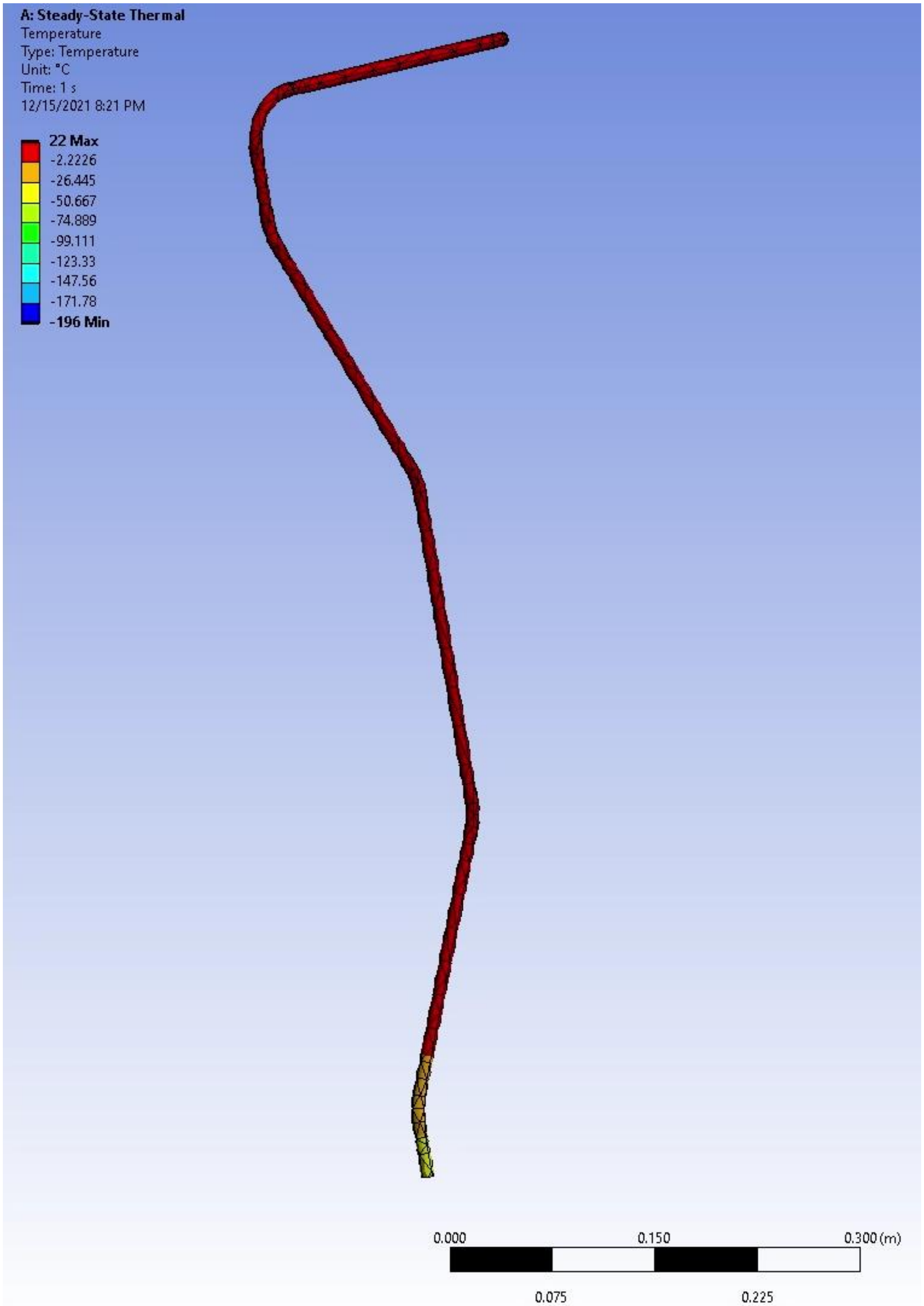


FIGURE 1-2-3: Temperature Contour Plot of the region 200mm above from submerge line (300mm above from the horizontal face of the hook)

Problem 1 – 3

Temperature probes on the handle simulation show the handle stays above -55 degrees Celsius at all points (of course probes cannot cover every node, but the general idea is illustrated in the screenshot below). The user is free to hold the tool without gloves.

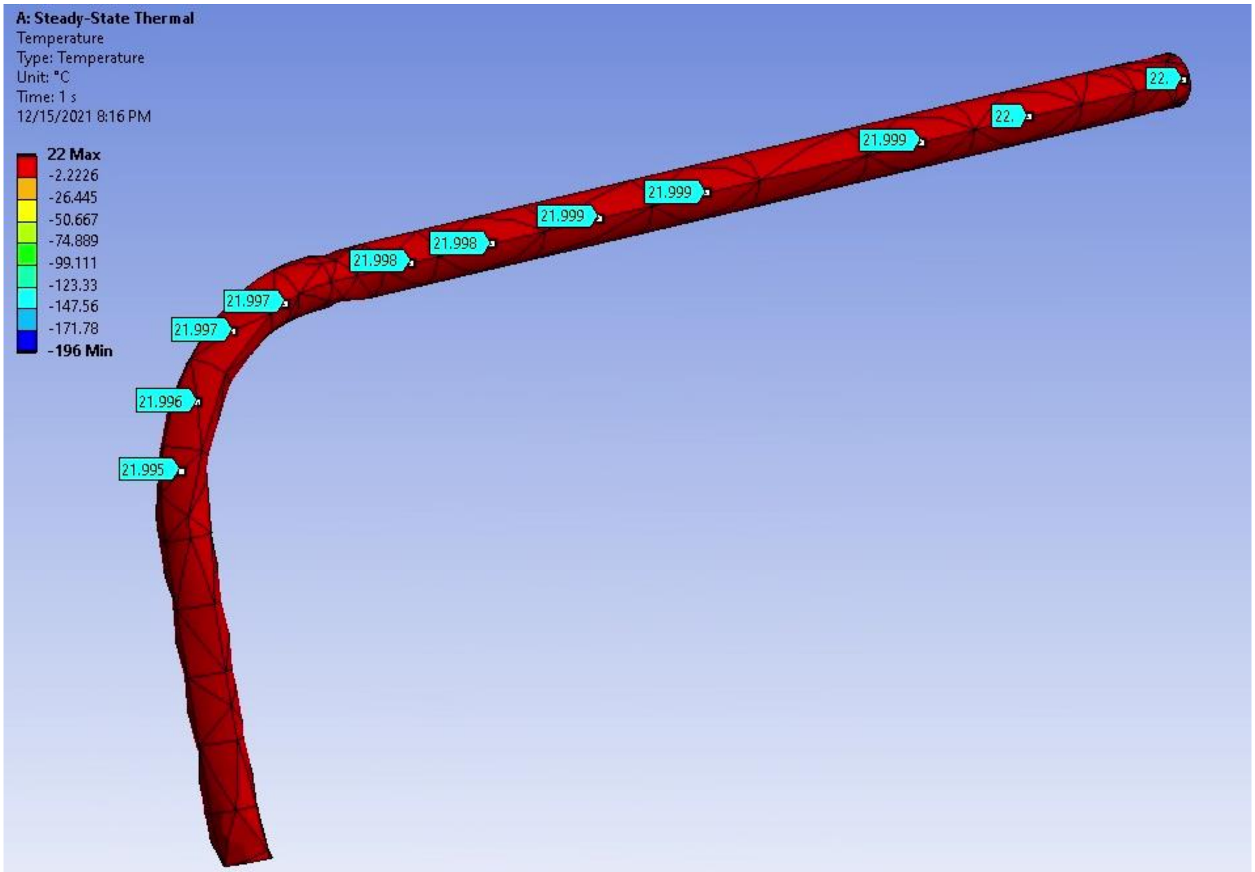


FIGURE 1-3: Screenshot of Temperature Contour Plot of the Horizontal Handle (Cut 900mm from submerged surface

Problem 1 – 4

A CAD model of the hook to be submerged in liquid nitrogen was created. This model was simulated with a fixed temperature boundary condition below a specified submerged point and exposed to convection on all faces outside above the submerged point.

The results obtained was a temperature contour plot, and a convergence study shows that the analysis is fairly accurate. Looking at the handle, we can see that the temperature remains well above -55 degrees Celsius which is the temperature where below that value would harm human skin.

Our analysis showed that the handle is above 21 degrees Celsius meaning it is safe to touch with human hands. If one is looking for temperature distributions in the hook itself, a more zoomed in photo would be required.

PROBLEM 2-1

Steady state temperatures

Node	**Steady State Temperature**
1 (closest to water)	**100**
2	**99.351**
3	**98.962**
4 (free end of spoon)	**98.829**

Problem 2-2-1 (temp distribution after 15 minutes)

Node	Steady State Temperature
1 (closest to water)	**100**
2	**60.05**
3	**35.016**
4 (free end of spoon)	**27.361**

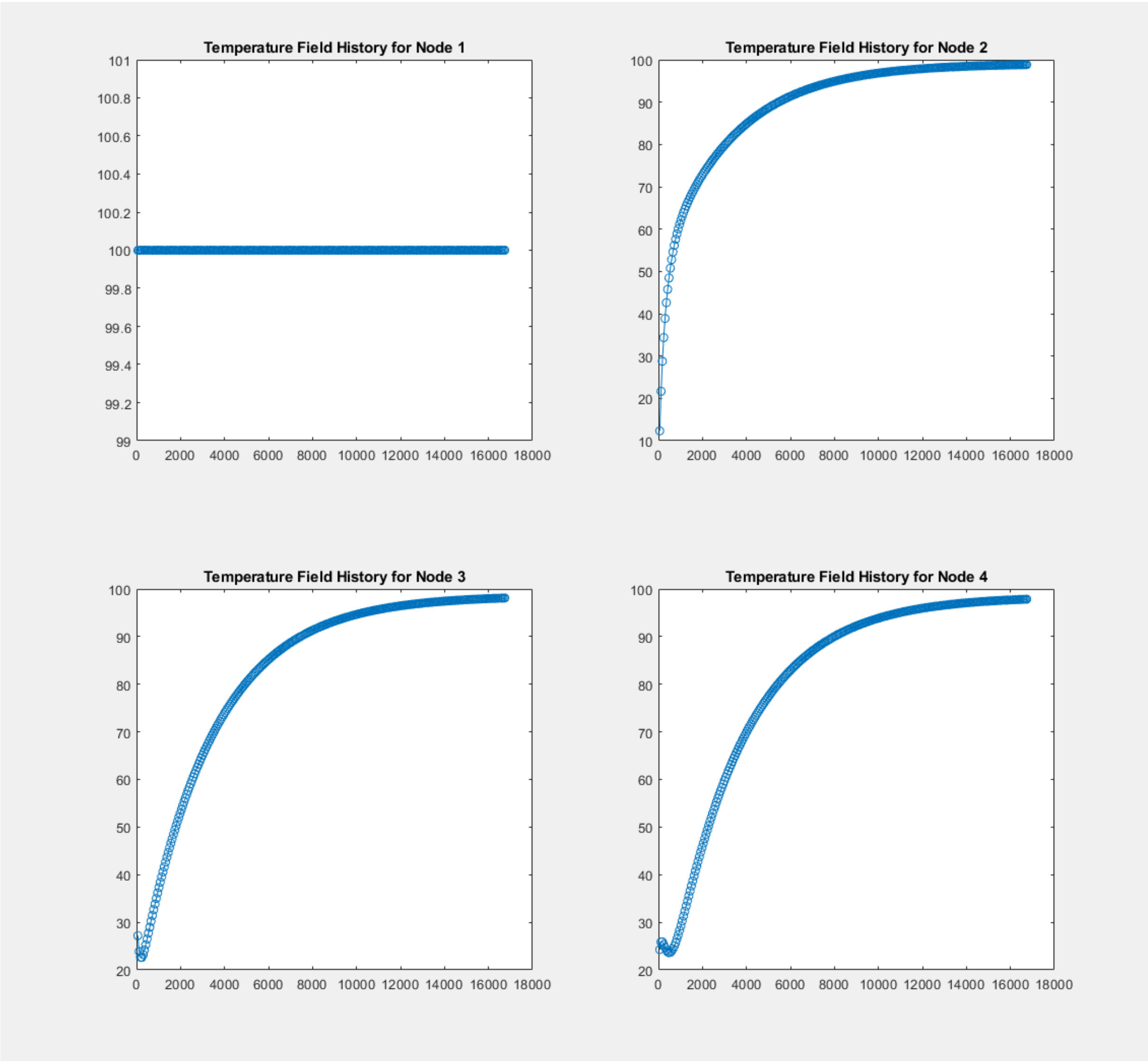
Problem 2-2-2 (how long to reach steady state condition ?)

NOTE: I don't have the computer power or time to find a tolerance of 10^-4, I do have the time to get 10^-2. The answers are almost the same as it's a logarithmic graph, and it tends towards steady state

Nodal Temperatures at tolerance steady state (taken from earliest possible)

Node	Steady State Temperature
1 (closest to water)	100
2	98.844
3	98.111
4 (free end of spoon)	97.858

Seconds taken to reach steady state: 16740 (279 minutes)



Problem 3 – 1 (I hate this table, but summarizes the code)

See MATLAB code for details calculations, shows:

- **All partial derivatives taken in the J matrix**
- **All symbolic functions used (converted from what's given) are in the F matrix**
- **"Any(error(:) >= tolerance) == 1" checks if all fractional relative error conditions are satisfied**

Iteration	$\begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix}$	$\begin{Bmatrix} f_1 \\ f_2 \\ f_3 \end{Bmatrix}_{x_i,y_i,z_i}$	$\begin{bmatrix} \frac{\partial f_1}{\partial x} & \frac{\partial f_1}{\partial y} & \frac{\partial f_1}{\partial z} \\ \frac{\partial f_2}{\partial x} & \frac{\partial f_2}{\partial y} & \frac{\partial f_2}{\partial z} \\ \frac{\partial f_3}{\partial x} & \frac{\partial f_3}{\partial y} & \frac{\partial f_3}{\partial z} \end{bmatrix}_{x_i,y_i,z_i}$	$\begin{bmatrix} x_{i+1} \\ y_{i+1} \\ z_{i+1} \end{bmatrix}$
1	$\begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$	$\begin{bmatrix} -6 \\ 2 \\ -1.3171 \end{bmatrix}$	$\begin{bmatrix} -7 & 1 & -1 \\ -2 & 13 & -2 \\ 1 & 1 & -8.9194 \end{bmatrix}$	$\begin{bmatrix} 0.13592 \\ 0.6699 \\ 0.71845 \end{bmatrix}$
2	$\begin{bmatrix} 0.13592 \\ 0.6699 \\ 0.71845 \end{bmatrix}$	$\begin{bmatrix} 1.5947 \\ 0.29092 \\ -0.062259 \end{bmatrix}$	$\begin{bmatrix} -9.9446 & 1 & -1 \\ -2 & 11.346 & -2 \\ 1 & 1 & -8.4943 \end{bmatrix}$	$\begin{bmatrix} 0.29554 \\ 0.67452 \\ 0.73046 \end{bmatrix}$
3	$\begin{bmatrix} 0.29554 \\ 0.67452 \\ 0.73046 \end{bmatrix}$	$\begin{bmatrix} 0.014456 \\ 4.2843e-05 \\ -9.5291e-05 \end{bmatrix}$	$\begin{bmatrix} -9.738 & 1 & -1 \\ -2 & 11.365 & -2 \\ 1 & 1 & -8.5103 \end{bmatrix}$	$\begin{bmatrix} 0.29704 \\ 0.67481 \\ 0.73066 \end{bmatrix}$
4	$\begin{bmatrix} 0.29704 \\ 0.67481 \\ 0.73066 \end{bmatrix}$	$\begin{bmatrix} 1.9831e-06 \\ 1.7518e-07 \\ -2.6414e-08 \end{bmatrix}$	$\begin{bmatrix} -9.7353 & 1 & -1 \\ -2 & 11.366 & -2 \\ 1 & 1 & -8.5105 \end{bmatrix}$	$\begin{bmatrix} 0.29704 \\ 0.67481 \\ 0.73066 \end{bmatrix}$

Problem 3 – 2

Run matlab code attached for more details

Code output:

```
f(x) =

exp(-x)*sin(x)^2

evaluating directly:
     0.080843

evaluating using 3 point Newton-Cotes
     0.081617

evaluating using 2 point Gaussian Quadrature
     0.080324
```