HW 2.1

By

Team 01 - Joel Adriano, Brynn Jewell, Jacob Leonard, and Alex Rogemoser

MET 440 - Heat Transfer

Dr. Ayala

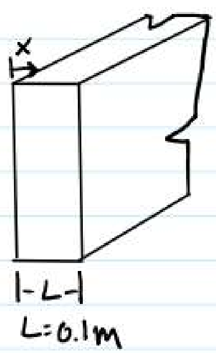
Ch5 Problems

Question 5-4

5-4 Consider a slab of thickness 0.1 m. One of the boundary surfaces, that at $x = 0$, is kept insulated, and the boundary surface at $x = L$ dissipates heat by convection with a heat transfer coefficient h into the ambient air at 150°C. The thermal conductivity of the wall is 40 $\mathrm{W/(m{\cdot}°C)}$, and within the wall energy is generated at a constant rate of 10^6 $\mathrm{W/m^3}$. Plot the temperature profiles in the slab for the heat transfer coefficients $h = 200, 350,$ and 500 $\mathrm{W/(m^2{\cdot}°C)}$.

Solution

4



@ $x=0$ ∴ Insulated

$x=L$ ∴ Disapates by Convection

$h=?$ (200, 350, 500 $W/m^2{\cdot}°C$)

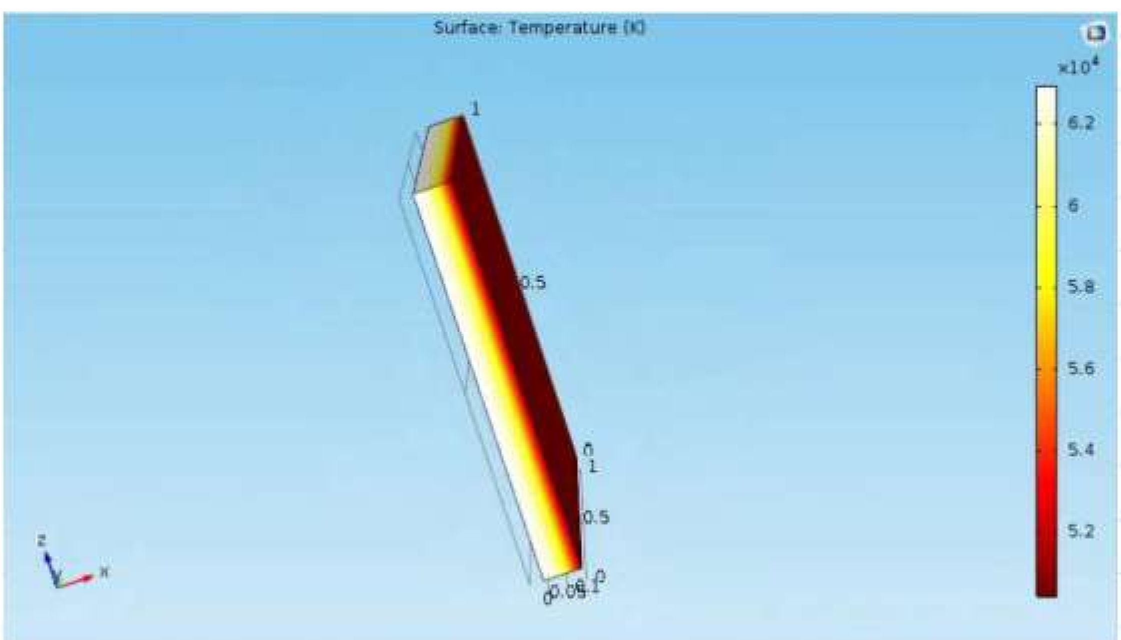
T_{air} 150°C

Wall:

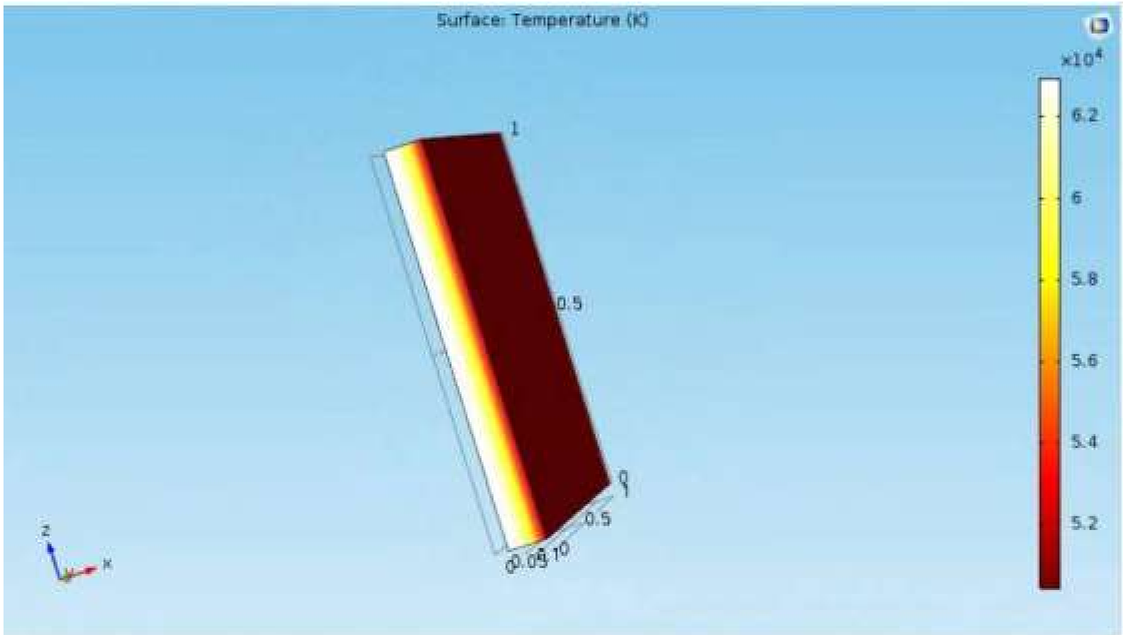
$K = 40 W/m^2{\cdot}°C$

Energy generation @ 10^6 W/m^3

h = 200

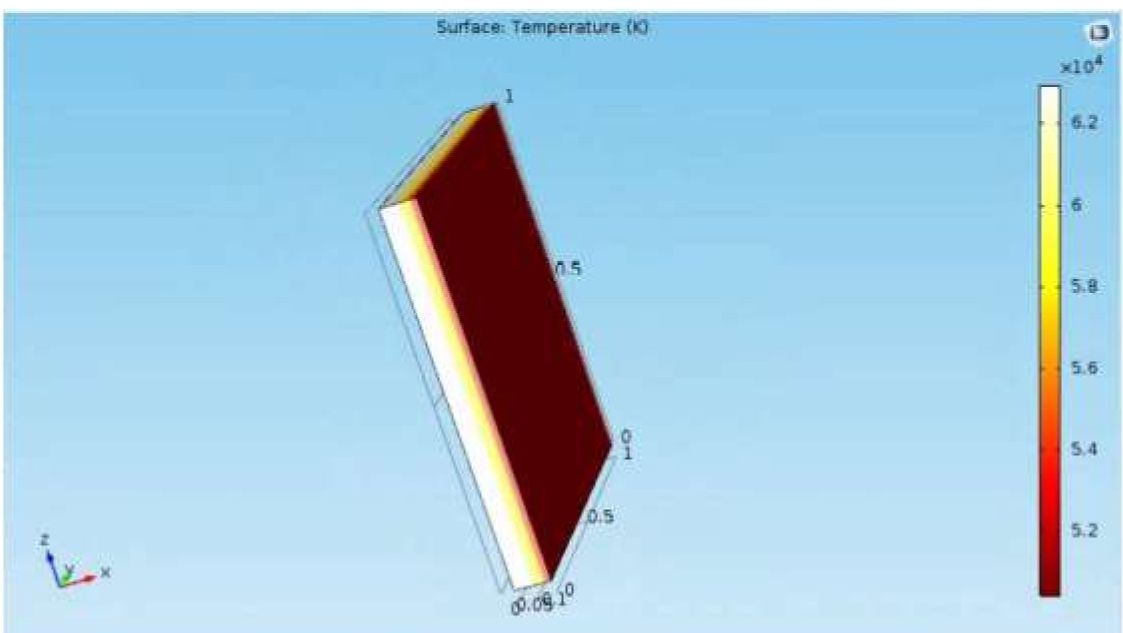


h = 350



Surface: Temperature (K)
×10^4
6.2
6
5.8
5.6
5.4
5.2
1
0.5
0
0.5
0.05

h = 500



Surface: Temperature (K)
×10^4
6.2
6
5.8
5.6
5.4
5.2
1
0.5
0
0.5
0.05

Question 5-26

5-26 Electric current $I = 500\ A$ flows through a stainless steel conductor of diameter $D = 5\ mm$ that has an electric resistance $R = 5 \times 10^{-4}\ \Omega/m$. Energy generated as a result of the passage of the electric current is dissipated by convection into an ambient at temperature $T_\infty = 0°C$ with a heat transfer coefficient $h = 50\ \mathrm{W/(m^2 \cdot °C)}$. The thermal conductivity of the conductor is $k = 60\ \mathrm{W/(m \cdot °C)}$. Calculate the center and surface temperatures of the cable.

Note:

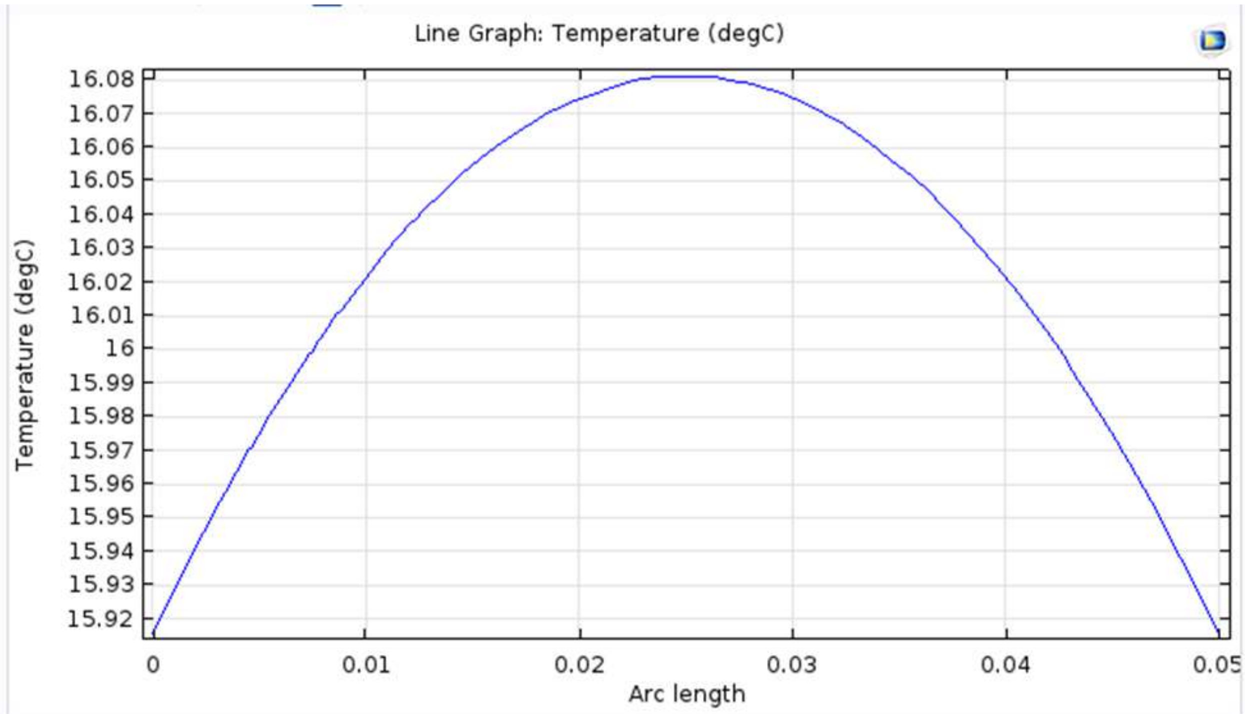
$$g = \frac{RI^2}{(\pi D^2/4) \times (1)} \quad \mathrm{W/m^3}$$

Solution

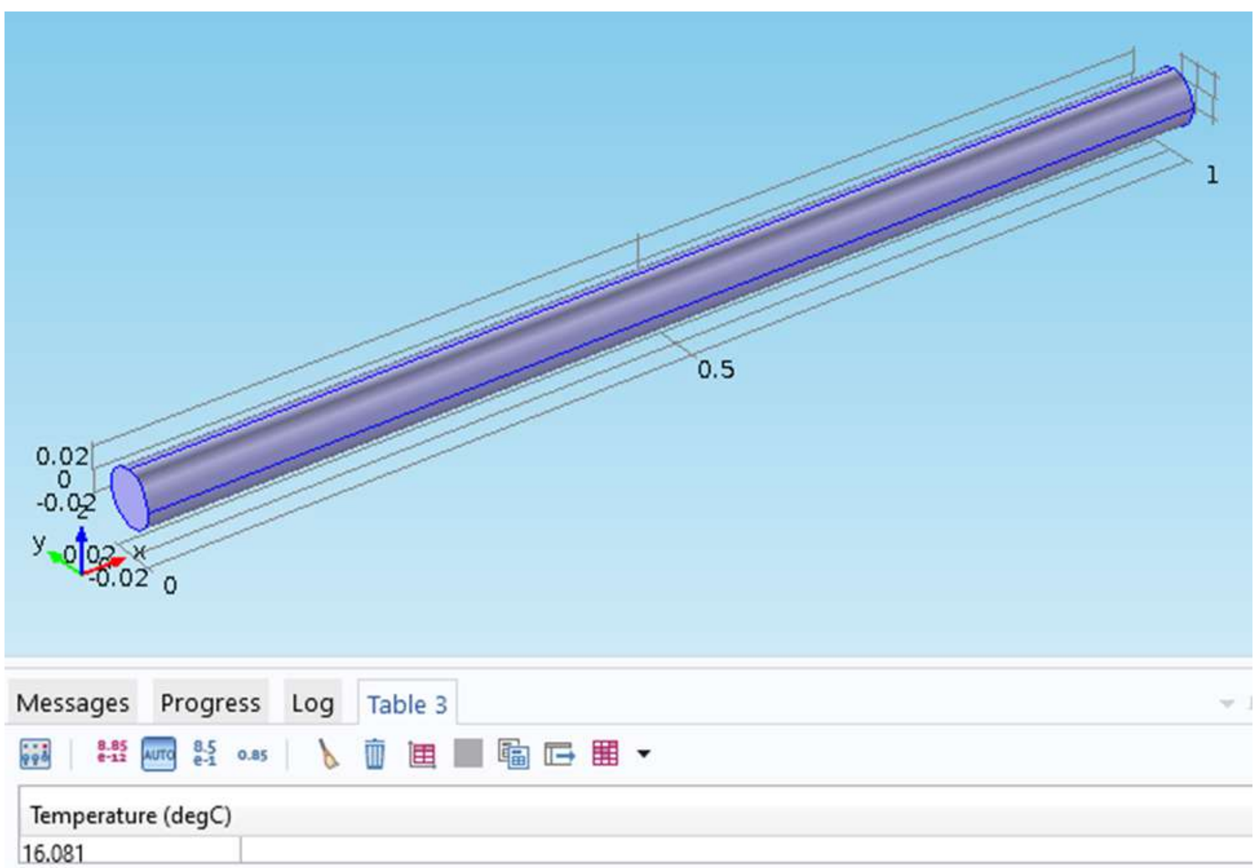
$$g = \frac{RI^2}{\frac{\pi D^2}{4} \times 1} = W/m^3$$

$$g = \frac{\left(5 \times 10^{-4} \frac{\Omega}{m}\right)(500\ A)^2}{\frac{\pi}{4} \cdot 0.05 m^2 \cdot 1}$$

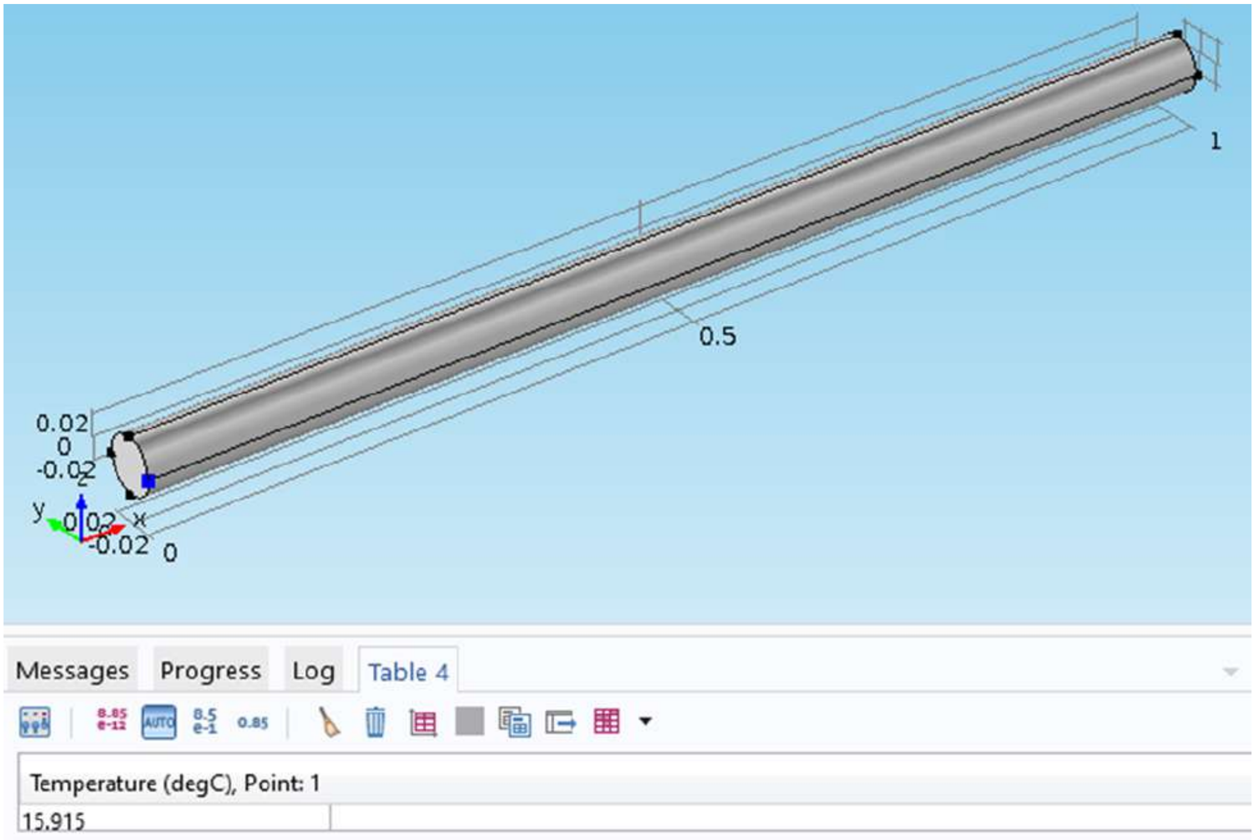
$$\checkmark\ g = 63662\ W/m^3$$



Center temperature of cable = 16.081°C



Surface Temperature of Cable = 15.915°C



Question 5-29

5-29 Consider the following one-dimensional, steady-state heat conduction problem:

$$\frac{d^2T(x)}{dx^2} + \frac{g}{k} = 0 \qquad \text{in } 0 < x < L$$

$$\frac{dT(x)}{dx} = 0 \qquad \text{at } x = 0$$

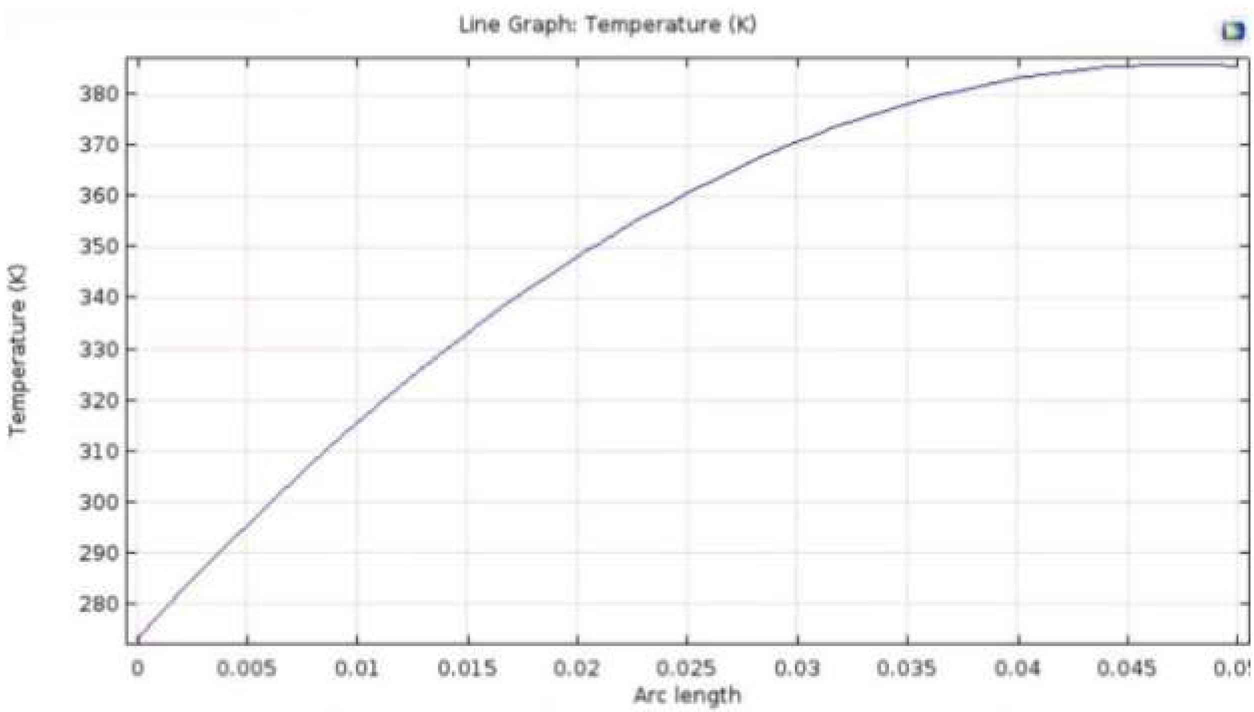
$$-k\frac{dT(x)}{dx} = h_\infty[T(x) - T_\infty] \qquad \text{at } x = L$$

(*a*) Write the finite-difference formulation of this heat conduction problem by dividing the region $O \leq x \leq L$ into five equal parts.

(*b*) Compute the node temperatures for $k = 10$ W/(m·℃), $h_\infty = 200$ W/(m^2·℃), $T_1 = 0$℃, $T_\infty = 100$℃, $g = 10^6$ W/m^3, and $L = 5\ cm$.

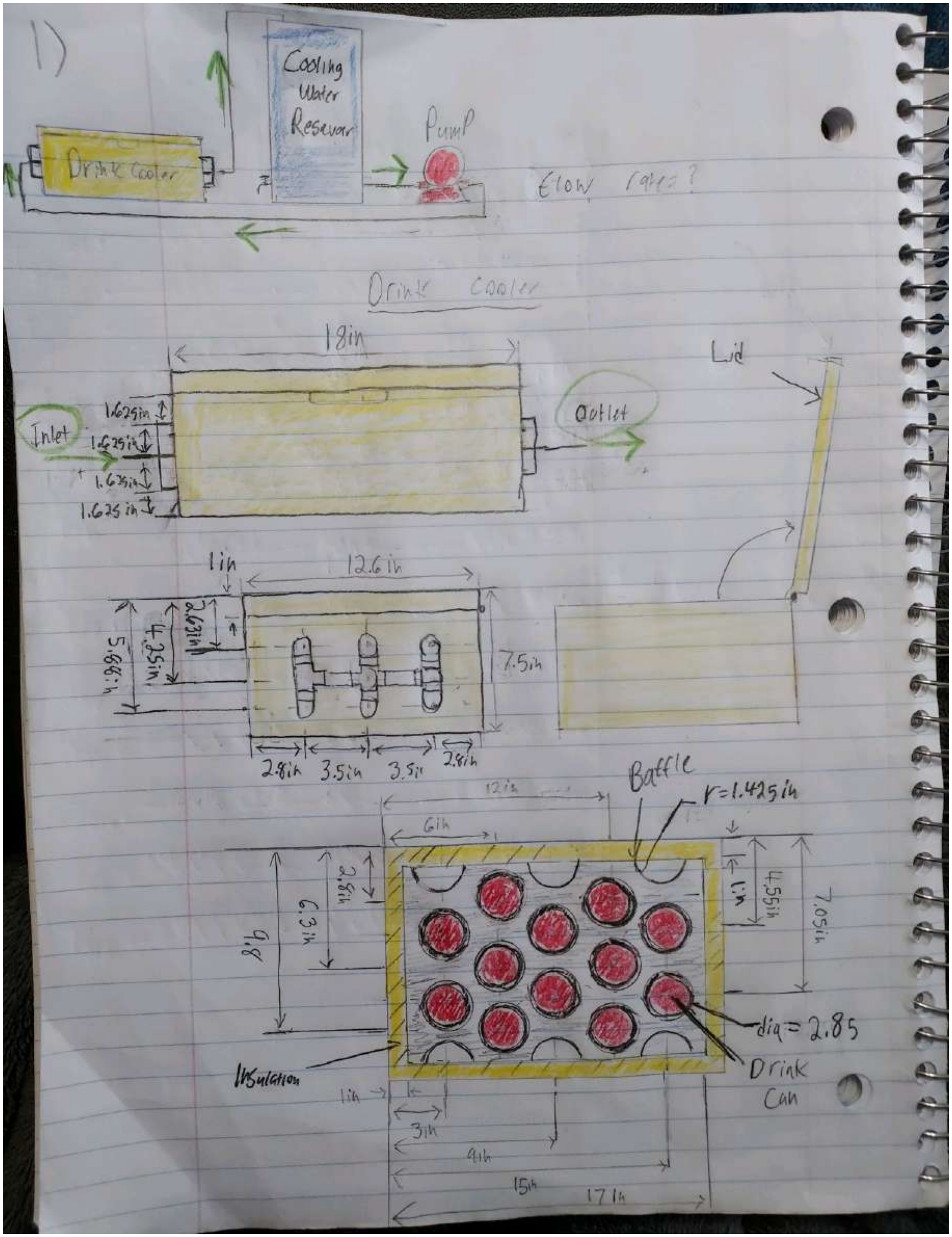
(*c*) Compare the numerical solution at the nodes with the exact solution.

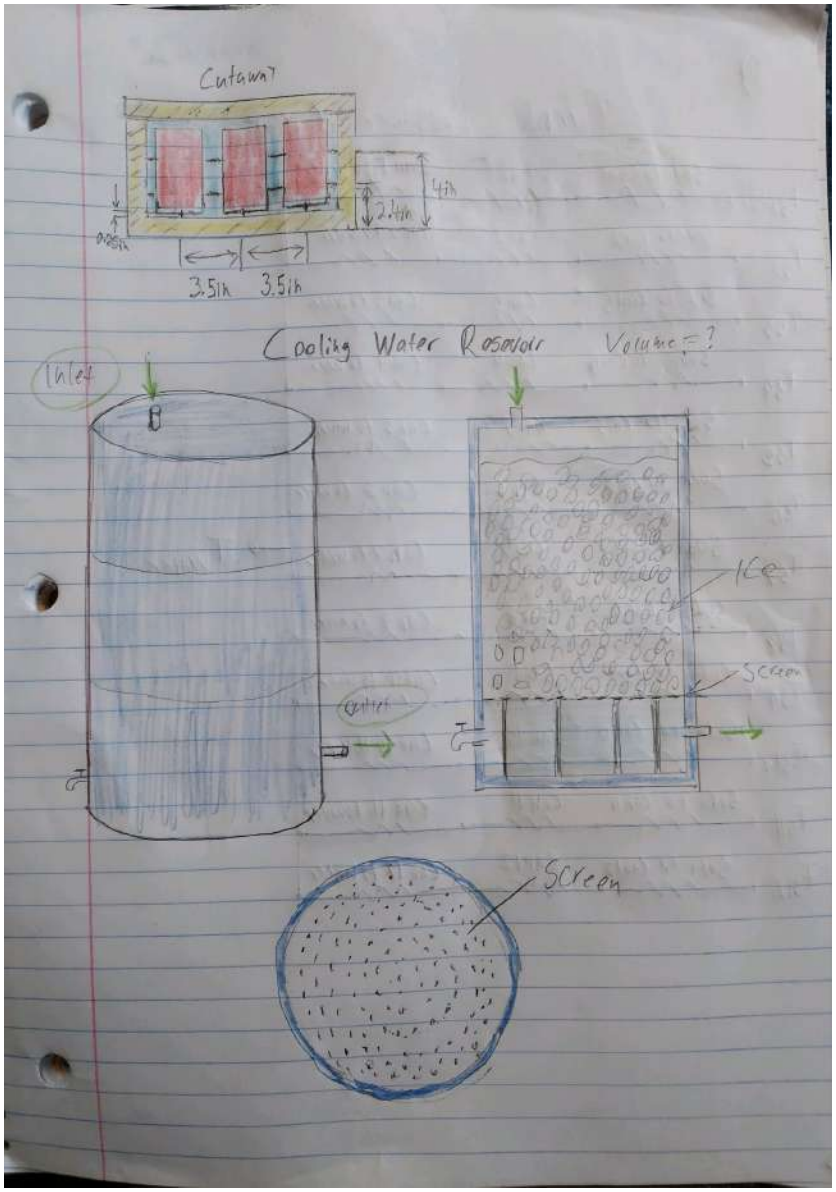
Solution



Presentation - 3 drawings of current ideas to cool down a six-pack in five minutes.

Proposal #1

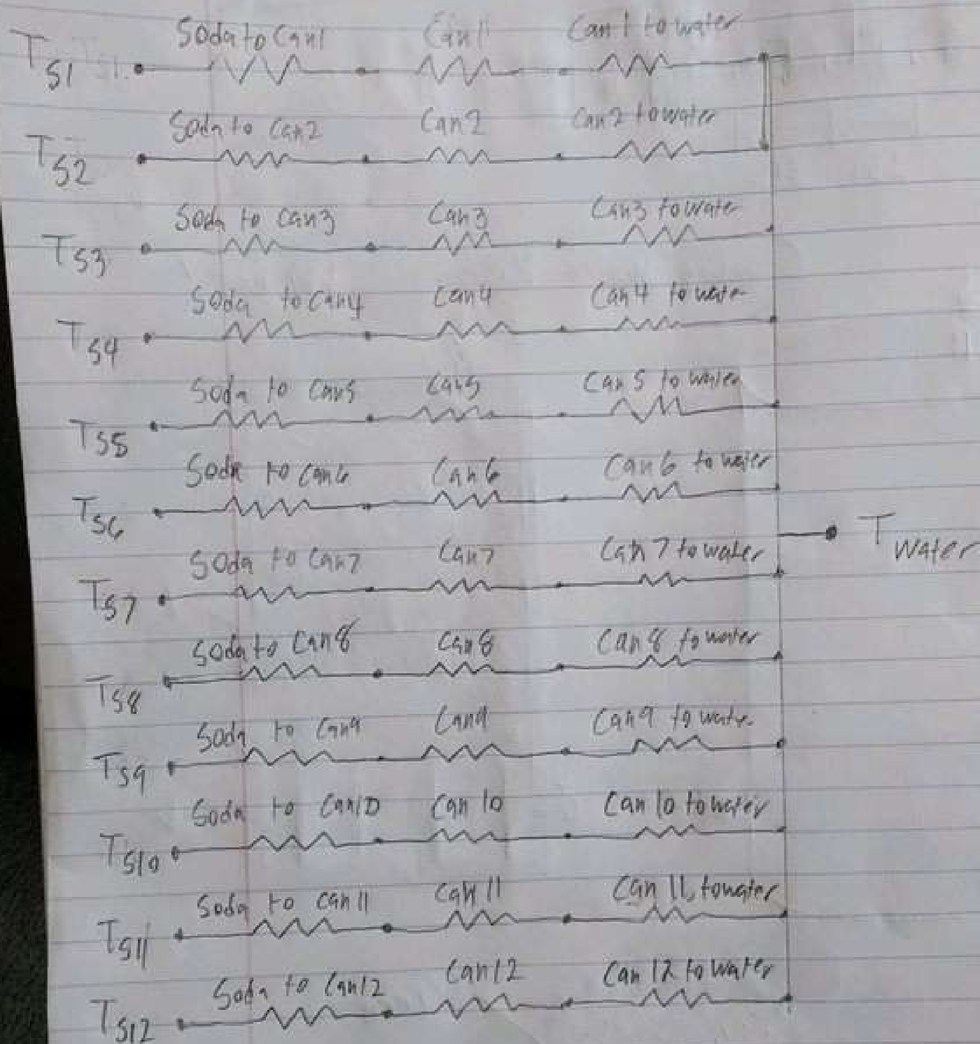




The concept of thermal resistances and the thermal circuit are very applicable. Instead of having to calculate the heat transfer for each thermal resistance, the heat transfer can be calculated from start to end since the resistors can be added in series or parallel. For this project, the circuit starts inside the cans and ends in the cooling water. It makes those calculations much easier to be able to solve for heat transfer using the thermal resistance equivalent and delta T. The thermal resistance of a hollow cylinder is applicable as well to find the resistance of the can due to conduction.

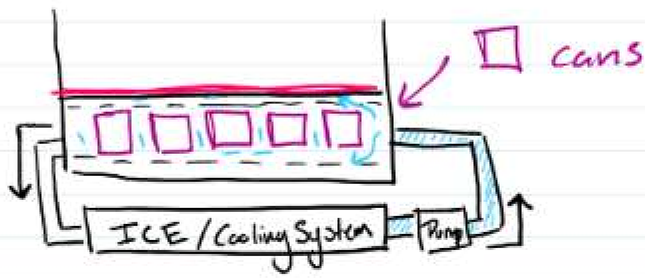
3)

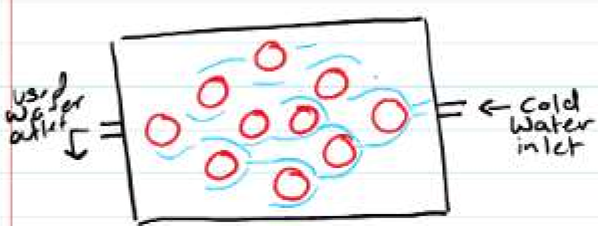
Thermal Resistance Circuit



Proposal #2

Final Project Sketch





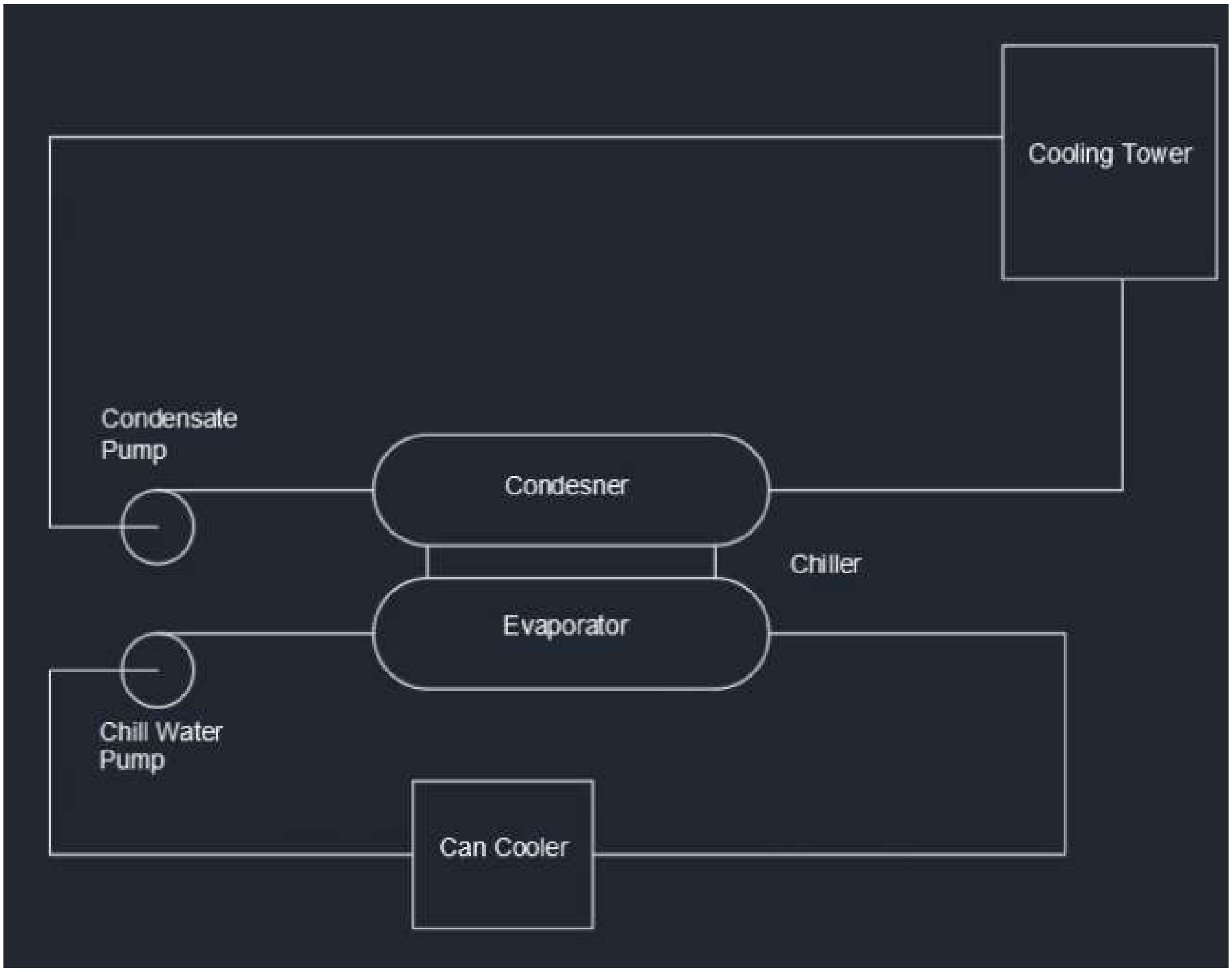
-> the cans will be enclosed is mesh to allow for complete contact with cold water

-> water will be forced between cans for cooling

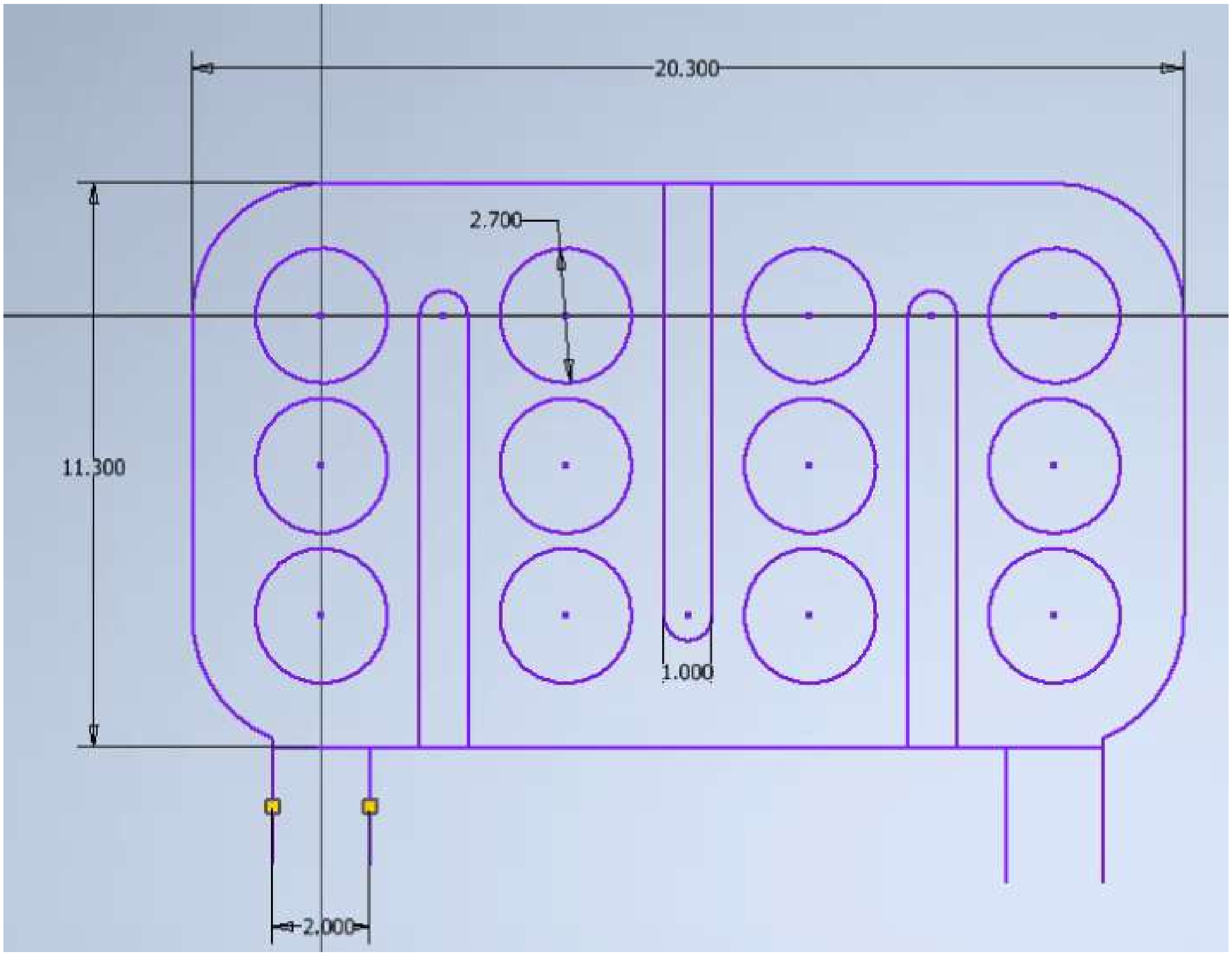
-> cans should ~~be~~ spaced for even cooling

Proposal #3

Overall system



Can cooler



Baffles in the can cooler ensure chilled water flows past each one. The exact dimensions are as yet undetermined. Pump capacities will ensure adequate can temperature quickly.