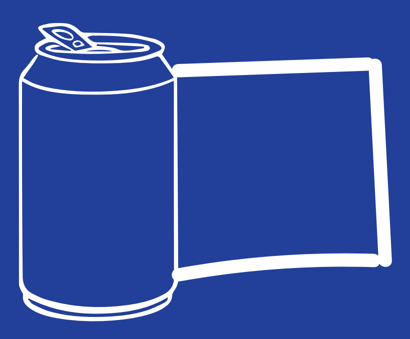
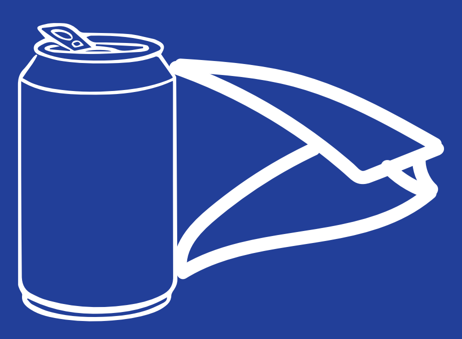
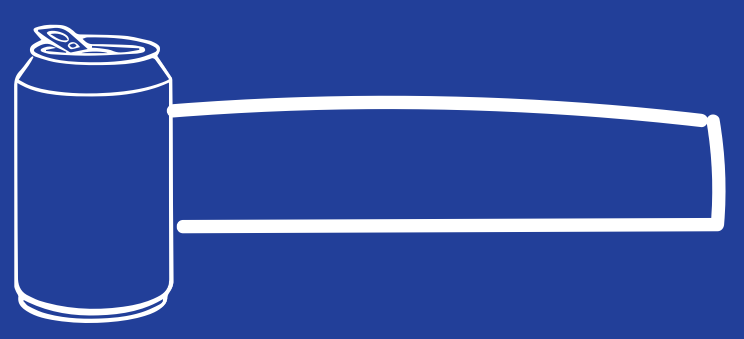

Rectangle Fin


U Fin


Chimney Fin


Long Fin

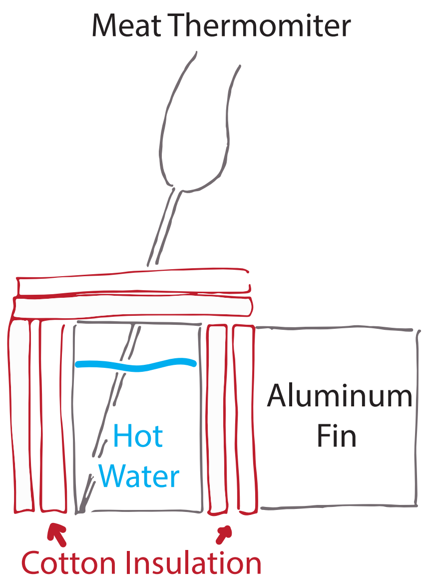
How does the Shape of a Fin Effect Heat Transfer?

Description

The system we plan to model and measure would be an insulated aluminum can of hot water with fins of varying sizes and numbers attached to the outside. The fins would vary from one test to another to determine which traits of the fins are most advantageous for cooling. We would measure the temperature of the water in the cup over time to evaluate which fin variations cause the liquid in the cup to cool the largest amount.

Our Model and Assumptions

The assumptions we used to create this model were that all the heat energy leaving the can left through the fin, the area and the material properties are consistent throughout the fin, conduction only happens in one dimension, and convection is uniform across the surface area of the fin.



Where this System Exists in the Real World

There are many instances where keeping a liquid cool in real life is advantageous but specifically for an example of this scale vehicles that have lots of suspension travel need to cool the oil in the shocks to retain its fluid properties and therefore the oil is held in finned reservoirs.

Where we Learned this Material

A similar probelm to the one we're choosing to model was given to us in homework week 7 question 4: Design a heat sink to keep a CPU cool.

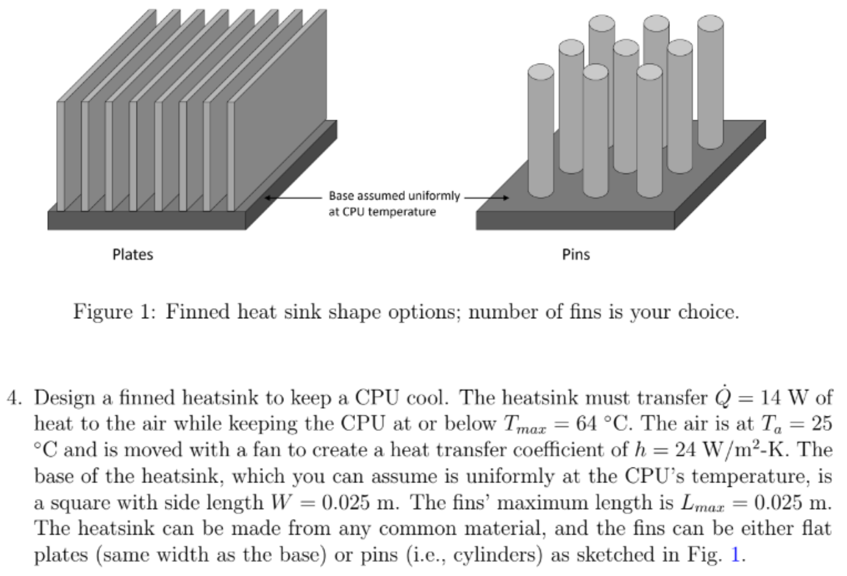


Figure 1: Finned heat sink shape options; number of fins is your choice.

4. Design a finned heatsink to keep a CPU cool. The heatsink must transfer $\dot{Q} = 14$ W of heat to the air while keeping the CPU at or below $T_{max} = 64$ °C. The air is at $T_a = 25$ °C and is moved with a fan to create a heat transfer coefficient of $h = 24$ W/m^2-K. The base of the heatsink, which you can assume is uniformly at the CPU's temperature, is a square with side length $W = 0.025$ m. The fins' maximum length is $L_{max} = 0.025$ m. The heatsink can be made from any common material, and the fins can be either flat plates (same width as the base) or pins (i.e., cylinders) as sketched in Fig. 1.

Analytical model

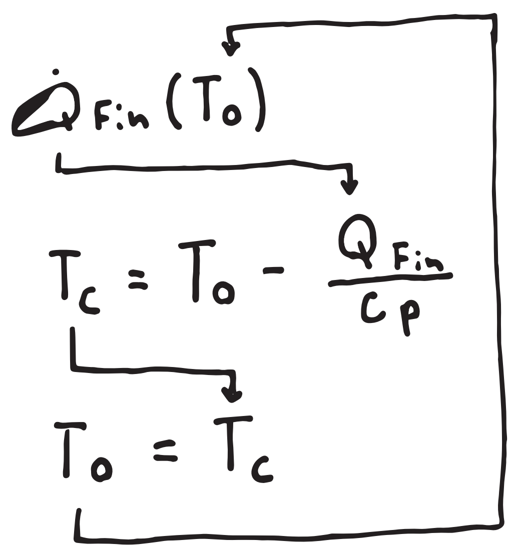
Our model makes use of two equations:

$$\dot{Q}_{Fin} = \sqrt{kAhP}\,(T_0 - T_\infty)\tanh(mL)$$

The equation for the heat transfer rate out of a fin

$$\dot{Q}_{syt} = c_p\,(T_0 - T_c)$$

The equation for net heat transfer from a system



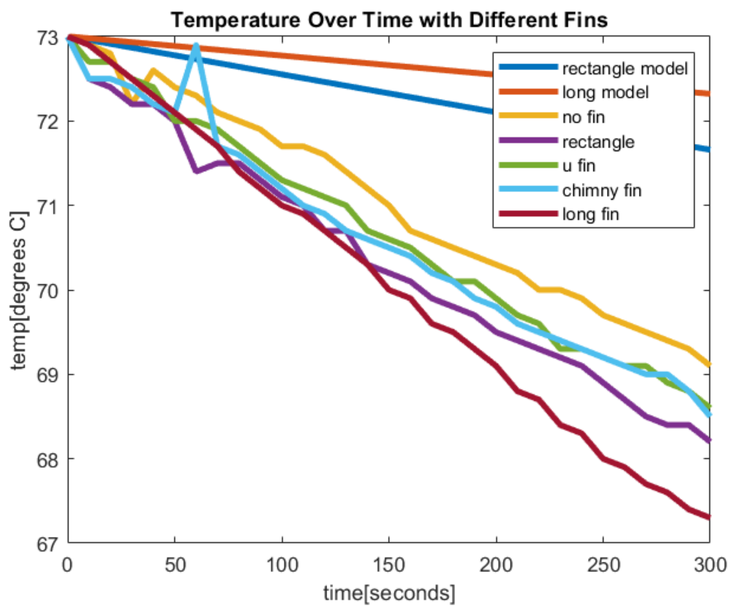
$$\dot{Q}_{Fin}(T_0)$$

$$T_c = T_0 - \frac{\dot{Q}_{Fin}}{c_p}$$

$$T_0 = T_c$$

Using the fin equation, the dimensions and material properties of the fin, and the initial temperature at the base of the fin which we assumed to be equivalent to the temperature of the water, a heat transfer rate out through the fin could be calculated. Over the time span of a second this heat transfer rate is equivalent to the net heat transfer from the temperature at the start of that second to the temperature at the end of a second as the units of heat transfer rate are joules/Second and the units of heat transfer are joules. This relationship then allowed us to solve for the temperature after one second elapsed to yield the difference in temperature over one second. By then repeating the same process with the temperature after another second the next temperature could again be found. Repeating this process the same number of times as we wanted seconds modeled we were able to analytically model a temperature over time graph.

Conclusions



We noticed that 2D shaped fins were the best for the amount of time we measured. In testing the elongated fin did the best so we originally believed that it was reaching the semi-infinite conduction point, however, when we ran our analytical model we found that the long fin should be less efficient than the rectangular fin. We believe this is because when attaching the fins to the can the long fin being half as wide only covered half the can causing more heat transfer outside of the fin causing the water to cool more quickly despite the fin being less efficient. The chimney and U shaped fin performed worse than the 2D fins due to the heat interacting in the middle meaning the gradient is not as efficient. The main takeaway is that the 2D shaped fins are the most efficient shape for fins because it has the most surface area exposed to atmospheric temperature air but any of the shapes of fin we tested are more efficient than no fin.

What to Improve

One avenue we could take to make our system more accurate would be to set up some sort of device to hold the thermometer in a more optimal and consistent position. While the thermometer was in roughly the same position for every test we found that even slight changes in thermometer position led to large changes in measured temperature, seen as spikes at the start of our tests, having some way of avoiding this perturbation in entirety would lead to more accurate results. Another avenue we could take is to improve our insulation around the can to make our assumption that there is only heat transfer out of the fin more realistic.

What we Learned

We learned that while the fin equation only applies to flat rectangular fins these were the most efficient types of fins we tested so when possible there is little reason to use fins other than these flat rectangular fins. We also observed that any small changes to the system such as bumping it when installing the insulating blanket caused the results to skew so devising ways to keep as much as possible constant is a necessity to get accurate results.