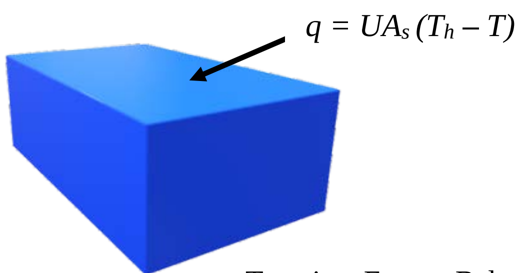
Heat Transfer Workshop 4 Introduction to Transient Lumped Capacitance

Name _______________

A simple model for systems with transient temperatures is the lumped capacitance method of analysis. This often works well for solid materials with high thermal conductivity. One often thinks of putting a piece of metal into a fluid at a different temperature which creates a step change in heat flux. However, it doesn't have to be a fluid. For example, your hands are often well perfused and make a good heat source.

Study the Lumped Capacitance Method in your heat transfer textbook. Draw the system and apply a transient energy balance for the piece of aluminum. The important assumption is that the temperature in the material is uniform in space, while it changes in time. Show the resulting algebraic solutions for the heat flux and temperature as a function of time, starting when the thermal event begins at time t_o with the initial temperature of the aluminum being T_i. Assume your hands remain at a constant temperature of T_h with an overall transfer coefficient to the metal of U. The specific heat of the aluminum piece is C and the mass is m. Show your analysis in the space provided below.



Transient Energy Balance:

$$mC\,\frac{dT}{dt} = q$$

Write out the symbolic solution:

The aluminum temperature as a function of time, T =

The surface heat flux to the aluminum as a function of time, q" = U (T_h – T) =

The exponential time constant for this process, τ =

Heat Transfer Workshop 4 Results

Name ______________

Use the piece of aluminum in your kit by putting the heat flux sensor on one side and then wrapping the cloth provided (in the kit) around it to provide some thermal resistance. First use the DAQ with the free thermocouple between your hands to record the steady temperature of your hands, T_h ___________. Then restart the data acquisition and place the aluminum piece with the heat flux sensor and cloth between your hands. Record the temperature and heat flux of the sensor at the surface of the metal for about one minute. Save the file. Based on the measured heat flux and temperature difference, assuming your hands stay at the same constant temperature previously measured, calculate an overall heat transfer coefficient at each time. Plot the values as a function of time and take the average, U = _____________

At what time does the thermal event start? t_i = __________

The mass of the aluminum block is about 14 grams and the dimensions are 2 in. by 1.25 in. by 1/8 in. thick. Calculate the corresponding surface area of the sides in contact with your hands,
Surface Area, A_s = ________

Use these values with the properties of aluminum (C = 900 J/kg-K) and the average heat transfer coefficient U to calculate the value of the time constant you found on the first page, τ = _____________.

Then use this time constant and the theoretical solutions of the lumped capacitance model from the previous page to predict the temperature and heat flux. Plot these predicted values along with the measured curves and compare. Attach your three plots as a function of time (Temperature predicted and measured, heat flux predicted and measured, and transfer coefficient, U).

1. How much variation of the overall transfer coefficient U was found over time?

2. Why is the value of U not actually constant?

3. How well does the predicted temperature curve based on the calculated time constant and initial temperature difference match the measured curve?

4. How well does the predicted heat flux curve based on the time constant, average heat transfer coefficient and initial temperature difference match the experimental values?

5. How did the metal piece **feel** as a function of time during the test?