From: Dallin Romney
Subject: 2D Conduction

Attachments: 5 plots, 1 image

Summary
The purpose of this laboratory experiment is to model 2-dimensional heat flow in a plate using the heat equation, and compare it to measured data. The measured temperatures are captured using an infrared camera and the computed temperatures are calculated by applying the Gauss-Seidel method to the finite difference numerical approximation, given the same boundary conditions as the measured values. Computations were performed using MATLAB and ended up being very similar to the measured results. In conclusion, the finite difference method is an accurate and appropriate tool for predicting 2-dimensional heat flow.

Results
Figure 6 shows the image produced by the infrared camera, while Figures 1-5 are generated by MATLAB from the data and computations. Figure 1 is a plot of the measured values, which looks very similar to the camera output (Figure 6). Figure 2 is the computed temperature field using the Gauss-Seidel and finite difference methods with the measured boundary conditions on the top and sides and an adiabatic boundary condition on the bottom. This looks impressively similar to Figure 1. Figures 3 and 4 show isotherms for the experimental and computed values, respectively. Note that the measured isotherms are jagged while the computed ones are smooth. Figure 5 shows the difference between experimental and computed values (computed subtracted from experimental). The contour plots (Figures 1, 2, 5) have 100 colors and the isotherm plots (Figures 3, 4) contain 17 isolines.

Discussion
1. The average temperature difference between the measured and computed values is 0.206 °C, or 0.70 % from the average of the measured data. In general, the lower right side of the computed plots are the least accurate. Figure 5 shows that the biggest temperature difference is in the bottom right region of the plate, by far. That maximum difference is 4.24 °C, or 14.5 % from the measured data. The differences aren't uniform throughout the plate because the material isn't perfect, it may not have reached steady state, and there was probably some measurement error on the bottom right corner.

2. The boundary conditions used in the computed model (Figure 2) were the exact measured values on the right, top, and left sides of the plate. The bottom side was modeled as adiabatic. The adiabatic assumption appears to be appropriate, because the temperature hardly changes at all throughout the bottom several rows of data (~1% across 5 rows of data). The boundaries with TEC's did not have very uniform temperatures, so a uniform temperature boundary would be

inappropriate. There was variation up to 10.5 °C on the left side of the plate, and around 5-8 °C for the other sides.

3. There were a few possible sources of error in this experiment, including error on the part of the camera measurement, the plate not quite being steady-state, the non-ideal nature of the plate (being non 2D), and non-uniform temperature distribution across the TECs. The plate setup was good, but a few things that might help are: getting the TECs closer to the plate edge, whether it means using smaller (and possibly more uniform!) TECs or making a shorter connection to the plate. I wonder if the insulation on the back causes the heat flow to be more 3D and less 2D: perhaps if the back conditions on the plate (insulated) were the same as the front conditions (open to the camera), the outward radiative flux would equalize and remove the 3rd dimension better. Although the adiabatic assumption appeared to be good, the results would have been slightly more accurate if measured temperatures were used at the bottom boundary, too.

Attachment: Figures and Tables

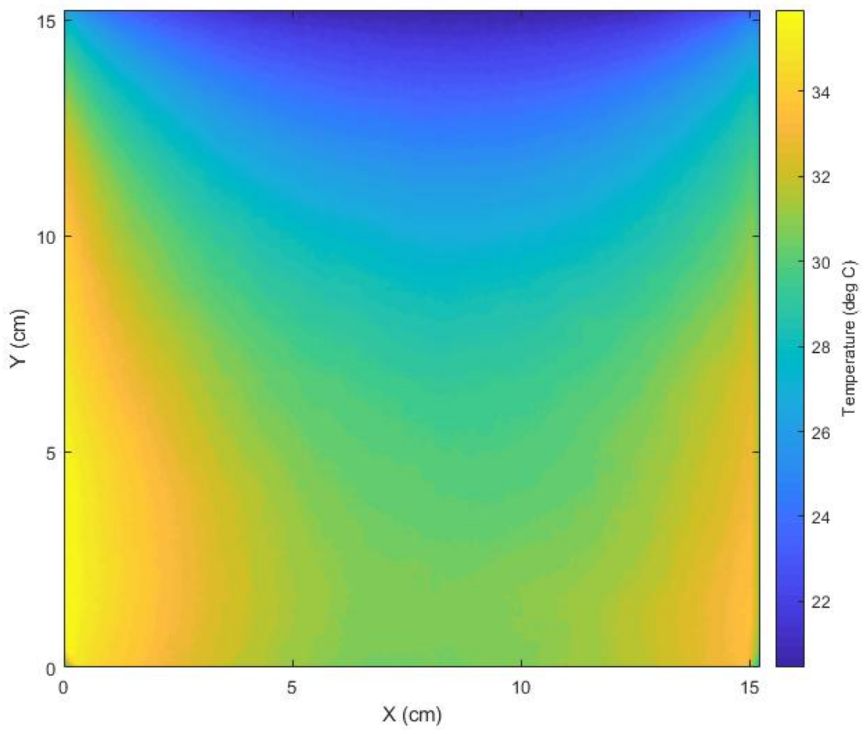

Figure 1. Contour plot of raw camera data temperature measurements

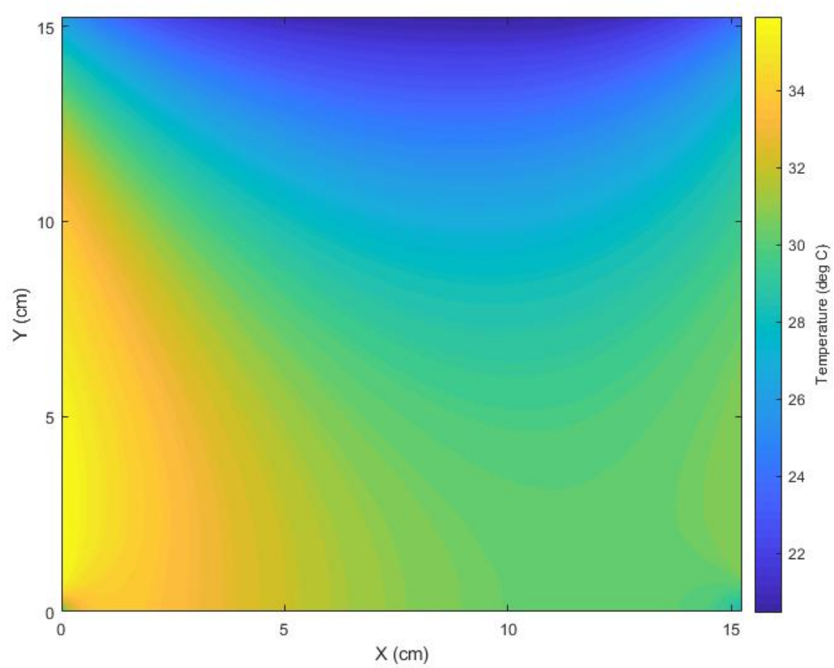

Figure 2. Contour plot of computed field based on measured/adiabatic boundary conditions

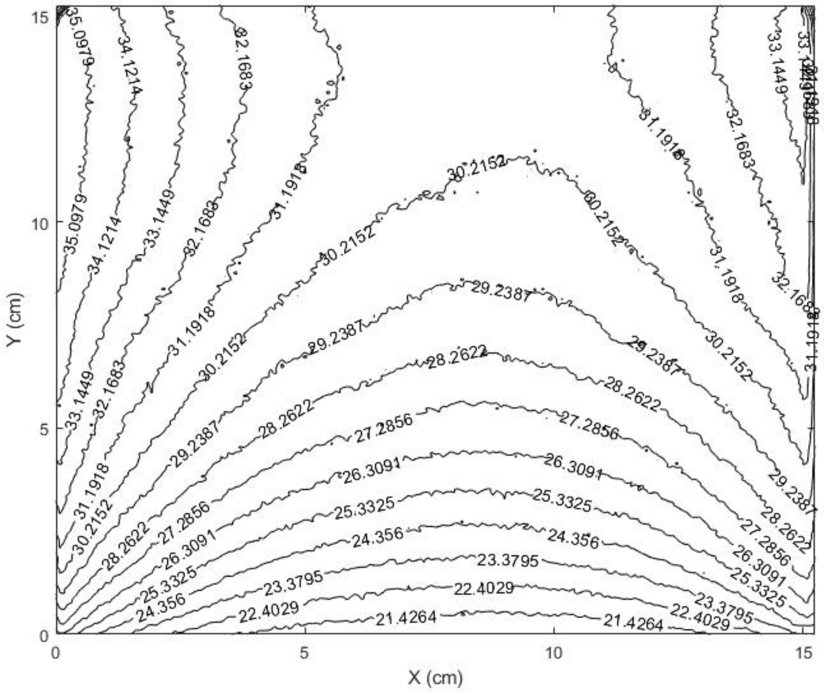

Figure 3. Measured isotherms for 2D temperature field (temperatures in deg C)

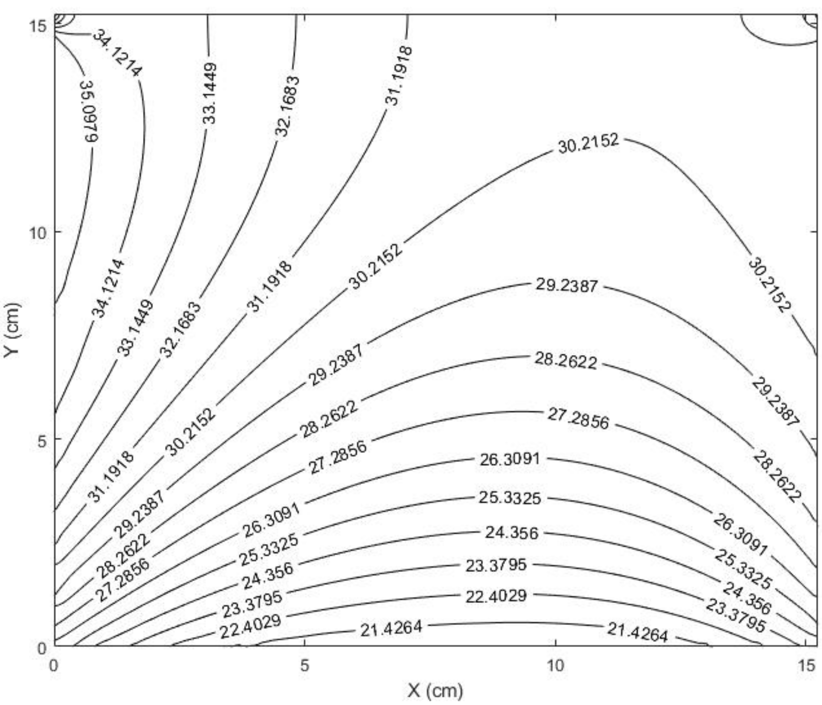

Figure 4. Computed isotherms for 2D temperature field (temperatures in deg C)

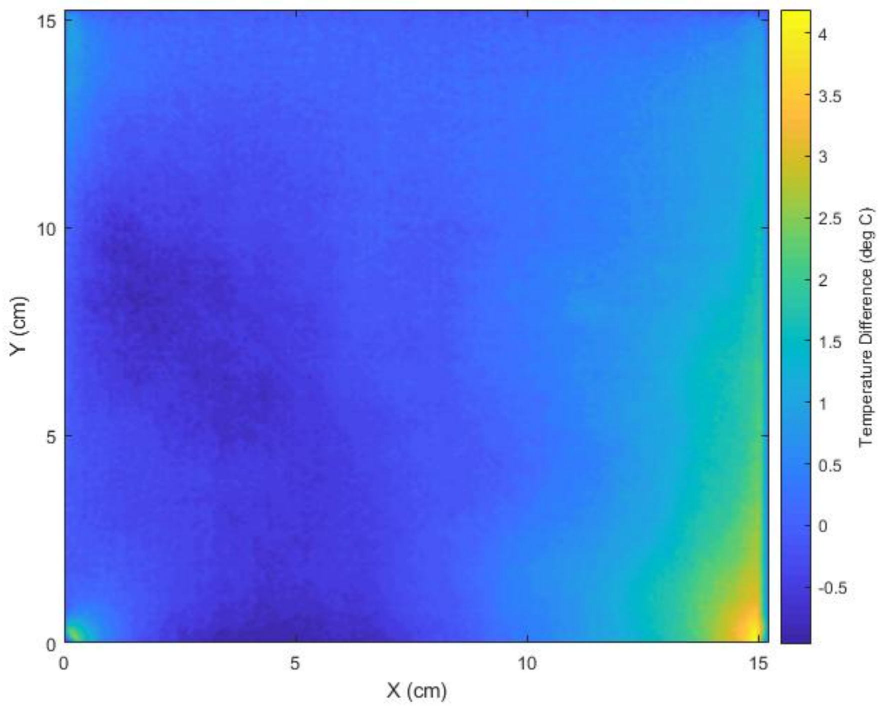

Figure 5. Difference between measured and computed temperatures (measured – computed)

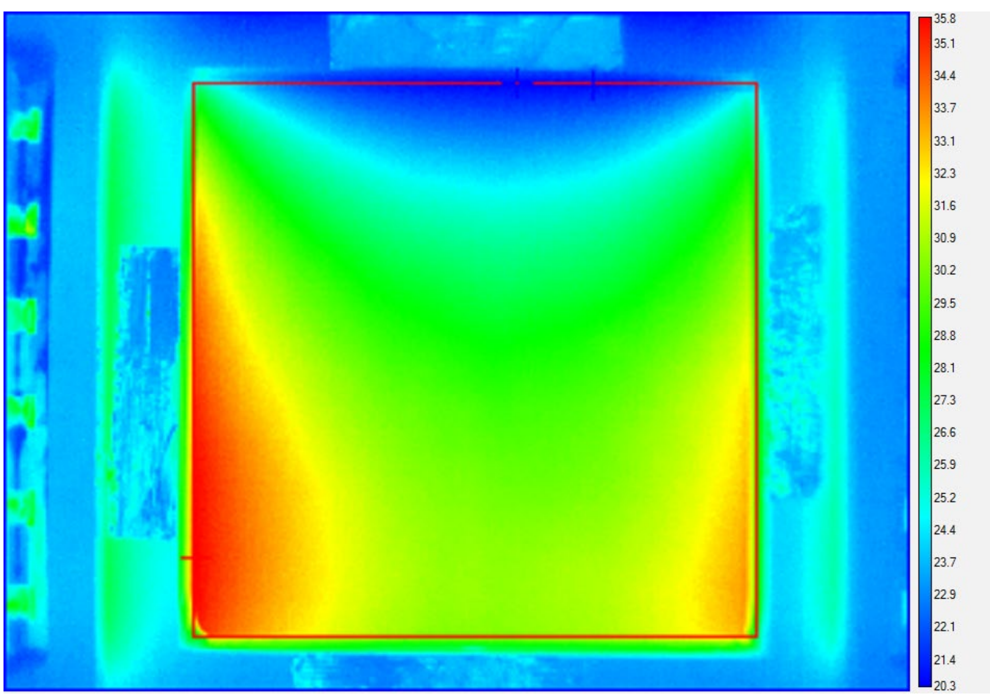

Figure 6. Image of 2D steady-state temperature field using FLIR T-420 infrared camera