TFES Lab (ME EN 4650)
Two-Dimensional Conduction

Required Figures

Captions

A meaningful and comprehensive figure caption must accompany all figures (plots and tables). The figure caption must include the following label: Figure 1x. where x denotes the letter a – d according to the plot order listed below or Table 1e. for the last figure. Use the following guidelines when writing captions:

→ Ideally, the figure caption should provide a "standalone" description of the plot, and contain enough information that the reader can understand what is being shown without having to refer back to the main text of the document (report, memo, etc.).

→ The caption should start with a statement of the quantities plotted on both axes. Typically the axis labels will utilize mathematical symbols (with appropriate units) for the quantities being plotted; however, in the caption, these quantities are described in words.

→ Include relevant contextual information about the plot. For example, you should state that the measurements were acquired under steady-state conditions. You can also state the camera make/model used for the measurements. For the temperature distribution from the numerical simulation, you should state the type of numerical method used.

→ When your plot includes errorbars, it is helpful to provide information in the caption about the errorbars. For example, you should include the fact that the errorbars represent a 95% confidence interval.

→ When comparing with published data, it is appropriate to provide a reference for the publication.

→ If in doubt about what information to include in the caption, one should err on the side of providing more information, rather than less.

Plots and Tables

1a. Provide two figures, displayed side-by-side: (i) a snapshot of the thermal image displayed by the IR camera, and (ii) a filled-color contour plot of the measured temperatures from the IR camera. Use 20 isotherms when generating the contour plot, and include a colorbar for your contour plot. The horizontal and vertical axes of the contour plot must be in units of cm (NOT pixels). Provide labels with appropriate units for the axes. Either provide a label for the colorbar on the plot, or include a description of the colorbar with correct units in the figure caption.

1b. Display the computed temperatures from your numerical solution in a filled-color contour plot with 20 isotherms. Be sure to include a colorbar. The horizontal and vertical axes must be in units of cm (NOT pixels). Provide labels with appropriate units for the axes. Either provide a label for the colorbar on the plot, or include a description of the colorbar with correct units in the figure caption.

1c. Display the percent difference between the measured and computed temperature fields in a filled-color contour plot with 20 isotherms,

$$\epsilon_{i,j} = \frac{|\tilde{T}_{i,j} - T_{i,j}|}{\tilde{T}_{i,j}} \cdot 100\% \,,$$

where $\tilde{T}_{i,j}$ denotes the measured temperature field from the IR camera, and $T_{i,j}$ denotes the corresponding temperature field from your numerical simulation. Be sure to include a colorbar. The horizontal and vertical axes must be in units of cm (NOT pixels). Provide labels with appropriate units for the axes. Either provide a label for the colorbar on the plot, or include a description of the colorbar with correct units in the figure caption.

1d. Create two subplots that show the temperature distribution along each of the edges as a function of distance along the edge, based on the measurements from the IR camera. The two subplots should be presented as follows:

(i) Plot the measured temperatures along the top and bottom edges. Plot temperature in °C along the vertical axis, and x-distance across the edge in cm along the horizontal axis.

(ii) Plot the measured temperatures along the left and right edges. Plot temperature in °C along the horizontal axis, and y-distance across the edge in cm along the vertical axis.

Use a solid line with a different color for each of the four edges. Indicate the mean value for each edge using a dashed line with the same colors. Supply a legend in each subplot (only for the solid lines NOT the dashed lines). Label the axes in each subplot with appropriate units.

1e. Calculate the net heat transfer rate, q, in Watts across each boundary based on the measured temperatures from the IR camera, and complete the table below. Note, these calculations will involve taking both numerical derivatives and numerical integrals. You MUST use second-order or higher methods, such as the forward/backward finite difference formulas or a Lagrange interpolating polynomial for the derivaties, and the trapezoidal rule or Simpson rule for the integrals. Note, a second-order forward/backward finite difference method will utilize three data points (pixels) in order to calculate the derivative.

Edge	q (W)	P_E (W)
Left		
Top		
Right		
Bottom		

Short-Answer Questions

2a. Quantify (in terms of a percentage) the average difference between the measured and computed temperatures, i.e., average $\epsilon_{i,j}$ spatially over the entire domain. Are there regions in the domain where the differences are greater than the average? Explicitly state the maximum percent difference, and indicate where that occurs in the domain. Are there any trends observed in the difference contour (e.g., are there larger differences in the center of the domain compared to the edges)? If so, explain why differences are not uniform across the entire domain. Based on your engineering judgment, is your numerical solution accurate (explain why or why not)? What can be done to improve the accuracy of your numerical solution? [4-6 sentences]

2b. How uniform are the temperatures along the left, top, and right edges? Quantify your answer in terms of a percentage based on the ratio of the standard deviation over the mean, i.e.,

$$2\,\frac{\sigma_T}{\overline{T}} \cdot 100\%$$

for each edge, where σ_T denotes the standard deviation along the edge and $\overline{T}$ denotes the average value along the edge. Note, the factor of 2 is used, because a spread of 2 standard deviations in a normal (Gaussian) probability density distribution captures 95% of the entire distribution, and thus yields a good measure of how far the measurements deviate from the average. Based on your engineering judgment, would it have been appropriate to assume a uniform temperature distribution along the left, top, and right boundaries in your numerical model (explain why or why not)? Does the measured temperature data along the bottom edge indicate that an adiabatic condition is appropriate for the numerical model (justify your answer)? [4 sentences]

2c. Based on your q calculations from Table 1e, estimate how much total power was required to heat/cool the boundaries of the plate in Watts. Assume that the TECs are 15% efficient in cooling mode and 95% efficient in heating mode, which are typical values specified for these types of devices. Compare these calculations to the actual measured electrical power supplied to the TECs. Explain any discrepancies between the two. [3-4 sentences, plus equations as appropriate]