Newton's law of cooling: Deliverables

ME 240: Fundamentals of Instrumentation & Measurement • D. H. Kelley and I. Mohammad • 98 points

Name: _____ Student ID: _____

Lab partners: _____

Please write the following sentence in the box below in your own handwriting and **SIGN**:
"I affirm that I have not given or received any unauthorized help on this assignment, and that this work will be my own."

Cooling rate measurement

1. (2 points) Dimensions of copper cube:

   length _____, width _____, height _____

2. (2 points) Dimensions of copper plate:

   length _____, width _____, height _____

3. (2 points) Dimensions of copper tube:

   length _____, outer diameter _____, wall thickness _____

4. (5 points) Predicted order magnitude (seconds, minutes, hours, etc.) of characteristic time τ? Explain your reasoning:

5. (5 points) Which object will cool fastest, and why? Explain your reasoning.

6. (4 points) Attach a plot showing a 10-s measurement of the ambient temperature. As with any plot, axes should be labelled and include proper units. Write a descriptive caption for the figure. A caption should always open with a brief and literal statement of what the figure shows (e.g., "Ambient temperature."). Give the reader all information necessary to understand what you're plotting and how, but don't repeat anything that's self-evident or appears in legends or labels. End with a one-sentence statement of the take-home message.

7. (2 points) Ambient temperature $T_a =$ _____

Ribbon temperature measurement

8. (1 point) Temperature near center of the ribbon: _____

9. (2 points) Temperatures at the two ends of the ribbon: _____, _____

10. (2 points) Dimensions of the ribbon:

    length _____, width _____, thickness _____

11. (1 point) Current in the ribbon: _____

Cooling rate analysis

12. (2 points) Measured cooling time τ for cube, with 95% confidence bounds:

    _____ (_____ , _____)

13. (1 point) Did your prediction lie within the 95% confidence bounds?_____

14. (2 points) Measured cooling time τ for plate, with 95% confidence bounds:

    _____ (_____ , _____)

15. (1 point) Did your prediction lie within the 95% confidence bounds?_____

16. (2 points) Measured cooling time τ for tube, with 95% confidence bounds:

    _____ (_____ , _____)

17. (1 point) Did your prediction lie within the 95% confidence bounds?_____

18. (6 points) Attach a plot showing all three sets of temperature measurements and their fit curves. The plot should have labelled axes with proper units and a legend. Also, write a descriptive caption for the figure.

19. (3 points) How close were your predictions to the measured characteristic cooling times? Same order of magnitude? Within a few percent? Did you typically over-estimate or under-estimate? Did you correctly guess which objects would cool fastest and slowest?

20. (3 points) Now imagine a copper rod of diameter 0.125 inch and length 1.4 m, whose mass would be 100 g, matching the other objects. Drawing on intuition gained from your measurements, would you expect a copper rod to cool faster or slower than the other objects? List them in order of increasing cooling time, according to your measurements and your prediction for the rod.

Ribbon temperature analysis

21. (4 points) Attach a plot showing the thermal image of the ribbon. Write a descriptive caption for the figure.

22. (3 points) Determine the pixel size in your image of the ribbon.

    position 1 (pixels): _____

    position 2 (pixels): _____

    pixel size: _____

23. (4 points) Attach a plot showing the rectangle on the thermal image of the ribbon. Write a descriptive caption for the figure.

24. (4 points) Attach a plot showing the temperature profile of the ribbon, as measured from your thermal image, and the corresponding fit curve. Axes should be labelled with proper units. Write a descriptive caption for the figure.

25. (2 points) Measured value of α for the ribbon, with 95% confidence bounds:

    _____ (_____ , _____)

26. (1 point) Value of $\rho_e \rho_m^{-1} C^{-1} \kappa^{-1}$ for the ribbon: _____

27. (1 point) Value of $\rho_e \rho_m^{-1} C^{-1} \kappa^{-1}$ for copper: _____

28. (1 point) Value of $\rho_e \rho_m^{-1} C^{-1} \kappa^{-1}$ for stainless steel: _____

29. (1 point) Value of $\rho_e \rho_m^{-1} C^{-1} \kappa^{-1}$ for carbon steel: _____

30. (1 point) Value of $\rho_e \rho_m^{-1} C^{-1} \kappa^{-1}$ for aluminum: _____

31. (2 points) Of what material is the ribbon composed? _____

32. (2 points) Value of the fit coefficient p_2 for the ribbon, with 95% confidence bounds:

    _____ (_____ , _____)

33. (3 points) We expected p_2 to be zero, but it isn't, exactly. What could have happened in this experiment to cause $p_2 \neq 0$? Hint: think about the heat sink temperatures.

34. (20 points) Type and attach an abstract for this exercise. That is, write a single paragraph in your own words that states the "big picture" of the exercise (why is it important?), the objectives of the exercise (primary deliverables and/or learning goals for the tasks), the methods you used to achieve those objectives, your results (including numerical values where possible), and a brief discussion of their accuracy. Also include a sentence summarizing potential future uses. Your abstract should be a concise summary of your work that stands alone.