ENPH257 Laboratory 2018

Due to space and apparatus restrictions, you will work in groups of four. What you submit for marks will be a group effort. There is one multi-part experiment.

Most important lab rule: Shoes must be worn at all times – no sandals or otherwise open footwear.

Heat Transport Laboratory

1. Tasks:

(a) Observe and measure **thermal waves** in an aluminum rod by modulating the heating at one end. In particular, demonstrate that part of the rod can be cooling as another part is heating.
(b) Compare each measurement to your own simulations and extract the conductivity and heat capacity of this aluminum alloy, plus heat loss parameters

2. You are provided with:

- Aluminum rod with cavities for temperature sensors and attachment screw for power resistor
- Power resistor, thermal paste for coupling
- DC adjustable power supply
- TMP36 temperature sensors, high temperature RTV to bond them in holes on rod
- Arduino board for data collection
- Breadboards for circuitry
- Plywood base to hold electronics
- Vessels to immerse the rod
- Hot water, ice
- SolidWorks (if desired as a check on your simulation code)

3. Overview:

Modulate the power of the heater and measure the resulting temperatures at various points along the rod, both as a function of time and position. Based on what you learn, and by comparing to your simulations, you are to estimate the:
• thermal diffusivity of the rod material, and thus the thermal conductivity and the specific heat capacity
• emissivity of the rod material
• convective heat transfer coefficient for this system
• fraction of power generated by the thermal resistor flowing down the rod

4. Getting started:

(a) You are provided with TMP36 temperature sensors; look up the specs and build a circuit to connect them to the Arduino. You will need to download an arduino support package and Arduino drivers (from the Arduino site). The computers in the lab are slow but fine for data taking (in Matlab or Python). You probably want to use your own laptop for the simulations; your professor uses a 2008 Toshiba Portégé with an SSD hard drive, i.e. you don't need the latest and fastest machine
(b) Make sure your power resistor is connected to convenient leads–solder some new wires if needed,

and/or insulate leads with heat-shrink tubing. Look up the maximum temperature of your resistor, and make sure it never exceeds that. We cannot afford to replace a dozen blown resistors!
(c) Attach your resistor tightly to the end of the rod, using a dab of thermal paste. Only a dab! The small pot must be enough for everyone.
(d) Attach sensors where desired. The TMP36s can be surface mounted or set into the rod by means of a 13/64" hole. Your challenge is to choose positions and measure T vs. time for each, compare to simulations, and from this comparison estimate the quantities above. See appendix for tips on writing DAQ code. Choose sensible and consistent colour coding for your wiring!
(e) Put some power into the resistor (make sure it does not get too hot!) and see what happens. There is no reason or benefit to exceed 70C (pain threshold).
(f) Think carefully about how to make particular measurements that emphasize one parameter over the others.
(f) You may program cooling measurements overnight, but there must be no active heating after the lab closes at 17:00.

5. Lab journal

Keep a lab journal (electronic, yellow lab book or part thereof, you choose). A knowledgeable reader (i.e. your prof or TA) should be able to reconstruct what your group (not just you!) did during the lab period, when, and in what order. It is a simple requirement; it is not easy to fulfill.
• When deciding what to write, imagine you will have to defend your actions of today in a court of law 10y from now!
• Graph your data during the lab period and scotch-tape the graphs into your journal (if paper).
• Analyze as you go.
• At the end of the day, write a brief summary with a job list for the next lab period.
• No loose pieces of paper

6. Analysis report

This will consist of nothing but properly captioned diagrams, graphs and a table summarizing your numerical results and uncertainties. You will be coached on how to do this in the tutorials. A reader with knowledge of the task you were assigned should be able to assess the quality of your work from these diagrams and graphs alone.

Checklist

Diagrams

- Captions
  - Informative (states what the reader needs to know)
  - Grammatical (makes logical sense)
  - Concise, just long enough
- Legible (big enough fonts, linewidths etc.)
- Good use of space (no "fluff", needless repetition or inclusion of "obvious" statements)
- Attractive (accurate proportions, colour use consistent and useful)

Graphs

- Captions
  - Informative (states what the reader needs to know)
  - Grammatical (makes logical sense)
  - Concise, just long enough
- Well labelled axes
- Useful, comprehensible legend
- Data and simulation on same plots and well distinguished
- Sensible uncertainties (aka “error bars”) indicated on graph or in caption
  - One-sigma or otherwise?
  - Point-to-point or systematic?
- Legible (big enough fonts etc.)
- Informative, grammatical caption
- Appropriate use of colour, line styles, widths etc.
- Good use of space (no “fluff”, needless repetition or inclusion of the “obvious”)
- Attractive layout

Do NOT add titles! The convention in physics journals is to put all the necessary information in the captions and legends.

Results Table

- Salient final results and uncertainties should be easy to read off the table
- Appropriate significant figures (with result and uncertainty agreeing in this regard)
- Experimental conditions relevant to any one result should be clear
- Clear and concise caption

Mark breakdown

Total 5% for interim report, 25% for final report
Mark by pair-wise ranking

“Lab citizenship” counts for an additional 5%, and this includes attendance, the appropriate seeking of help, response to suggestions and criticism, assistance to others, and leaving the lab by 17:00 at the latest (when we are all tired and hungry).

Submission

• Interim report due Friday June 15th 2018 at 17:00. One (only!) file named interim_analysis_group#.pdf to enph257@phas.ubc.ca
• Final report due Monday June 25th 2018 at 17:00. One (only!) file named final_analysis_group#.pdf to enph257@phas.ubc.ca

Hints and useful bits of MATLAB code

Save data (including the raw voltages) in files with informative names and the date/time included. Write write continuously as the experiment proceeds, not just at the end (your system may crash).

```
ts = datetime('now');
DateString = datestr(ts,30); filename = ['5Wpolished_horizontal' DateString '.xlsx'];
```