**ENPH257 Heat Transport Laboratory**

**Rules:**

Shoes must be worn at all times in the lab – no sandals or otherwise open footwear.

1. **Lab Goals:**

(a) Measure heat transport along and dissipation by an aluminum rod.

(b) Perform tests to distinguish and quantify contributions from conduction, convection, evaporation and radiation

(c) Compare each measurement to your own simulations

(d) Learn skills of experimental physics and materials research

(e) Complete experimental part by June 19; final report due July 2. DO NOT WAIT to compare data with simulations, or you may find yourselves stuck for the final paper without an option to repeat or fine-tune experiments. The extra time between June 19 and July 2 is for writing and making nice figures.

2. **You are provided with:**

(a) Aluminum rod and attachment screw

(b) Power resistor, thermal paste for coupling

(c) Room temperature sensor

(d) DC adjustable power supply

(e) Insulation of various sorts: a piece of blanket, a short section to tube, etc.

(f) Thermocouples, thermometers

(g) Arduino board for data collection

(h) DMMs

(i) Spray paint

(j) Beakers with water

(k) Odd collection of cooling fins

(l) SolidWorks

3. **Overview:**

The principle of this lab is very simple: you are to heat one end of an aluminum rod with a known power, and measure the resulting temperatures at various points along the rod, both as a function of time and in equilibrium. You can perform this measurement under a variety of different conditions. Let me give you a few possibilities (these are just examples–do what you see fit to achieve the lab goals):

(a) Bare rod

(b) Rod insulated along most of the length

(c) Bare, but covered with black paint

(d) Bare, with water to cool the end of the rod

(e) Insulated, with water to cool the end of the rod

Based on what you learn, and by comparing to your simulations, you are to estimate the:

(a) thermal conductivity of this particular aluminum alloy

(b) the specific heat capacity of this particular aluminum alloy

(c) emissivity of aluminum in different surface states

(d) convective heat transfer coefficient for this system in different conditions, geometries

(e) fraction of power generated by the thermal resistor flowing down the rod

(f) heat loss from a wet surface (cover part of rod with moist fabric)

4. **Getting started:**

(a) Get to know your thermocouples, and measurement electronics. Make thermocouple measurements with the voltmeter, then make an amplifier circuit and measure multiple thermocouples with the arduino (this will involve some programming, preferably in Matlab, to read the ar- duino).

(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 (you can use one of your thermocouples for this). We're can't afford to replace a bunch of blown resistors!

(c) Attach your resistor tightly to the end of the Al rod, using a dab of thermal paste. Only a dab! The small pot must be enough for everyone.

(d) You can make insulation of various coverages from your pieces of insulation, and attach ther- mocouples where desired. Your challenge is to make a few different setups, measure T vs. position vs. time for each, compare to simulations, and from this comparison estimate the quantities above. (The

number of setups you measure is up to you, but you will surely need at least three substantially different arrangements.)

(e) Now put some power into your resistor (again, make sure it does not get too hot!) and see what happens.

(f) You may make program cooling measurements overnight, but there must be no active heating after the lab closes at 17:00.

5. **Final report:** Your final lab report is to be written by you individually, although you can of course discuss your experiments with your class- and labgroup-mates. Guidelines for the final report:

(a) DO incorporate what you have learned through your measurements into a single cohesive paper, entitled “Heat transport mechanisms for an end-heated aluminum rod”.

(b) DON’T simply write a description of what you did each day

(c) DO combine simulations and data throughout the report, e.g., “we measured X and found Y. We simulated this experiment in solid works using the approximations A, B, and C, and found Z. In order to improve the simulation (to make Z closer to Y) we realized that approximation C is not valid, and instead should be replaced by D. Using approximation D, the simulation produced results YY: much better agreement with the experiment.”

(d) DO incorporate different measurements into each topic, e.g., “In order to estimate property A, we measured in configuration B, and found C. The accuracy of this estimate was improved, however, by taking into account the measurements in configuration D, giving E. These results are consistent with the results reported in section F, because G.

(e) DO present data quantitatively (graphs are frequently better than tables)

(f) DON’T present every single piece of data you took: your goal is to tell a story that is scientifically rigorous and honest, but I do not need to know details like: “First we measured the temperature and found it to be 240K, but then we figured out that the problem was we had forgotten put our voltmeter to the right setting”. If in doubt as to what to include, please ask!

(g) DO make clear schematics to illustrate your text.

(h) DO write 3-6 pages (no more!) of text (1000-3000 words, no more!), in latex, including figures and schematic drawings (but not the appendix). Exact length depends on your style of writing.

(i) DO include details of your simulations as an appendix. Simulation results belong in the main text; appendix contains full printout of simulation code and parameters so that we can reproduce your simulation.

(j) DO organize your paper into sections.

j) DO check spelling and grammar. Nothing sets a bad tone more than typos. Proofread, proofread, proofread! Get an uninvolved pair of eyes to look your paper over, maybe someone in Arts.

**Marking guide to the lab write-up** (35% total)

This is not an immutable list of section headings, but it is a list of things you should not forget.

Content

- Title: "Heat transport mechanisms for an end-heated aluminum rod", author, date
- Abstract – NOT needed
- Introduction
    - Physics background
        - Appropriate level
- Description of method
    - Clear diagram(s)
    - Beware of photographs (usually unparsable due to clutter – N.B. a photo of a breadboard is NOT a circuit diagram)
- Analysis
    - Presentation of results
- Discussion
    - Uncertainty analysis (no further than simple $\chi^2$ estimate)
        - Sources (realistic, justifiable, quantifiable)
        - Offsets
        - Scale errors
        - Noise
- Summary of results
- References (only include information out of the ordinary, i.e. DO NOT reference course notes, standard textbooks, wikipedia etc.)
- Acknowledgements (any external help – DO NOT include those who are paid to help you!)

Style

- Clarity of writing (inc. sentence structure, grammar, spelling…)
- Attractive, meaningful diagrams and plots
- Layout, logical order
- Within word and page limits

**Submission**

- Submit pdf (only pdf!) to Connect by file named "group#_familyname_enph257.pdf"
- Due 17:00 Thursday July 2nd 2015

Chris Waltham 2015.06.19