Name: Group member names:
Student number:

Physics 157 Tutorial – week of September 30th

In this tutorial, you will get some more practice with problems involving heat conduction and radiation. These will be good practice for the midterm, so we would like you to complete all the questions and hand them in for grading, in place of a homework set. **Submit the worksheet in the homework boxes before 5pm Monday the 7th. The correct answers are in the list on the last page.**

You may wish to refer back to the following general tips for solving conduction problems:

Conduction problem tips:

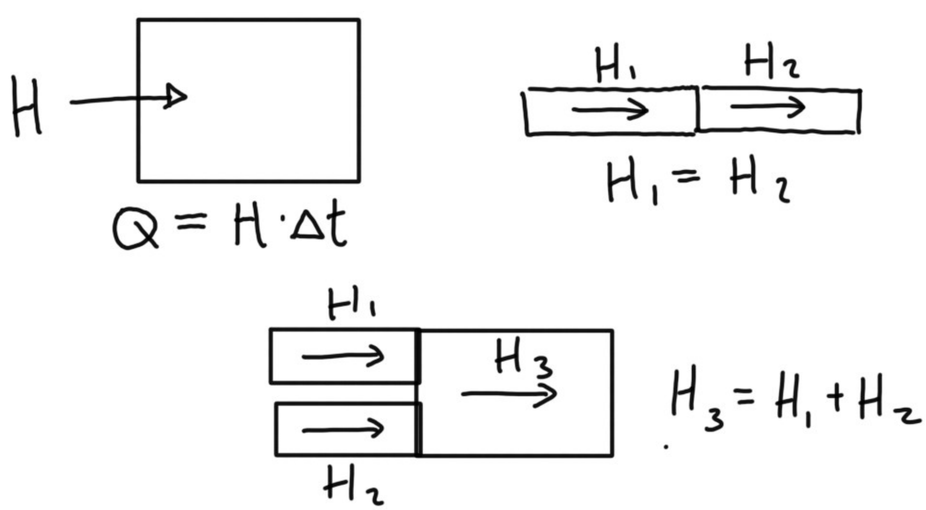
As usual, it's helpful to draw a picture and label it, and break the system into parts.

For the part or parts of the system through which heat is flowing, you will need the basic relation:

$$\mathbf{H = k\,A\,(T_H - T_C)/L}$$

For parts of the system undergoing a temperature or phase change, you will need the relation **Q = mL** or **Q = m c ΔT.**

Finally, you will need to relate the heat currents and heats for the various parts. For example, if a heat current H is going into a system, the amount of heat that enters in time Δt is Q = H Δt. If heat is flowing through two adjacent objects in series, the heat current is the same for both. If they are side-by-side, the heat currents add up. These ideas are summarized below:



Question 1: You're feeling hungry once again. Still unsettled by a previous restaurant experience, and trying to save some money, you decide to make some pasta at home. You put 2L of water into an aluminum pot with a base of area of $100 cm^2$ and thickness 0.4cm, put it on the stove, and turn on the heat. You start browsing Netflix, and just as you begin to watch an episode of your favorite vampire romance series, the water starts boiling. Unfortunately, the steam from your pot is nothing compared to the steaminess of the opening scene, and you become completely absorbed in the episode, forgetting about the water, the pasta, and even your hunger. It's not until the closing credits roll, 45 minutes later, that you remember the pot on your stove, and just at that moment, your smoke alarm sounds since the water has boiled away and the (somewhat dirty) pot has started to smoke.

What was the temperature of the burner under your pot?

(constants: k_{Al} =205 W/m/K , L_v = 2256 × 10^3J/kg)

If you are stuck, look at the hints on the last page and answer those questions one at a time.

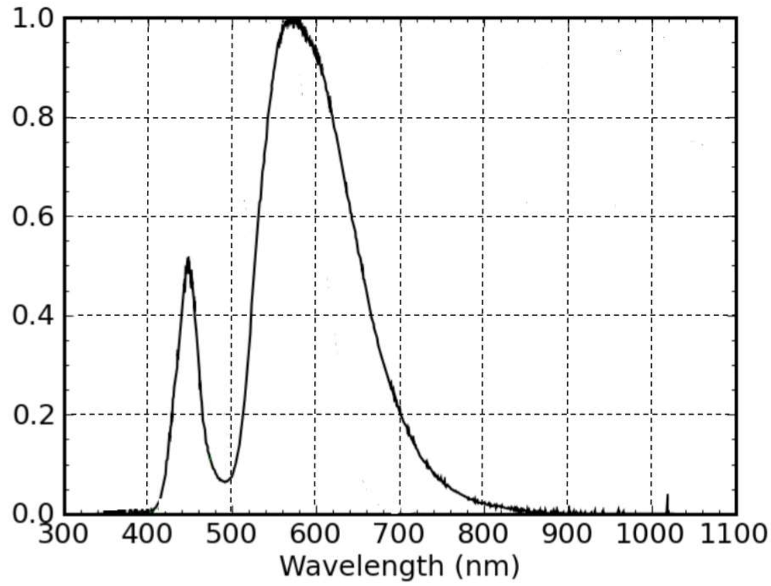
Question 2: A box-shaped single-story home has a height of 4 meters and horizontal dimensions 10 meters by 10 meters. The insulation layer around the house has an R-value of 15 for the walls and 20 for the floor and ceiling. Estimate the power of a furnace that would be required to keep this house at 20 ^{o}C if the outside temperature is 0^{o}C.

(recall: the R-value is related to the thickness L and conductivity k of an insulation layer. To find L/k in SI units from the R value, we multiply by 0.1761. For example, an R value of 10 means that L/k is 1.761 m^2 K/W. The ratio k/L that appears in the equation for heat current is just the inverse of this).

If you are stuck, look at the hints on the last page and answer those questions one at a time.

Question 3: Here's a relatively simple radiation problem from a recent midterm:

3. The picture below shows the spectrum of an LED light emitting the total of 10 W of electromagnetic radiation. The vertical scale is in arbitrary units. How much power does it emit in the infrared?



The point of this is that the graph shows how the power of the radiation is distributed between different wavelengths. The fraction of the total power radiated in a certain wavelength range is equal to the fraction of the area under the graph that lies in that range of wavelengths. For example, if we want to know the fraction of power emitted in wavelengths between 600 and 700 nanometers, we could shade in the region between the x-axis and the curve, and then estimate what fraction of this shaded area is in the vertical strip between 600 and 700nm. The grid on the graph should be helpful in estimating the area fraction.

Using this method, write a solution to the midterm question. Infrared radiation is the radiation with wavelength larger than 700nm. *There is a hint on the last page.*

Hints for question 1:

- How much heat is required to boil all the water?
- What is the heat current through the bottom of the pot (see the picture on the first page)?
- What is the temperature of the water while it is boiling away?
- If you know the heat current, can you figure out the difference between the burner temperature and the water temperature?

Hints for question 2:

- How does the power of the furnace relate to the total heat flowing out of the house?
- How can we calculate the total heat flowing out of the house if we have different R values for different surfaces (see the pictures on the first page)?
- What do we use for A in the heat formula?

Hints for question 3:

- You can use the squares on the graph as your basic unit of area when estimating the ratio. It can be helpful to subdivide the squares into smaller squares!

Possible answers: 1.15×10^{-5}, 9.17×10^{-4},0.00243, 0.0182, 0.5, 1.19, 1.99, 23.7, 103.3,142.8, 193, 916 2.35×10^{3}, 6.11×10^{3}, 2.14×10^{4}