Physics 157 Homework 1: due Wed, Sept 19th by 5pm

Hand-in boxes for each tutorial section are upstairs in the Life building. Write your name, student number, and tutorial section on your submission.

In class, we have talked about how macroscopic properties of physical systems (size, volume, appearance in visible light or IR, etc…) depend on their temperature. For a quantitative property of some material (i.e. something we can assign a number to), we can represent this dependence either by an equation or by a graph. From either of these, we can predict what the property will be at a certain temperature, or we can figure out the temperature from a measurement of that property (thus using the system as a thermometer). The goal of this week's homework is for you to become comfortable working with these quantitative relationships and to help you achieve the following skills:

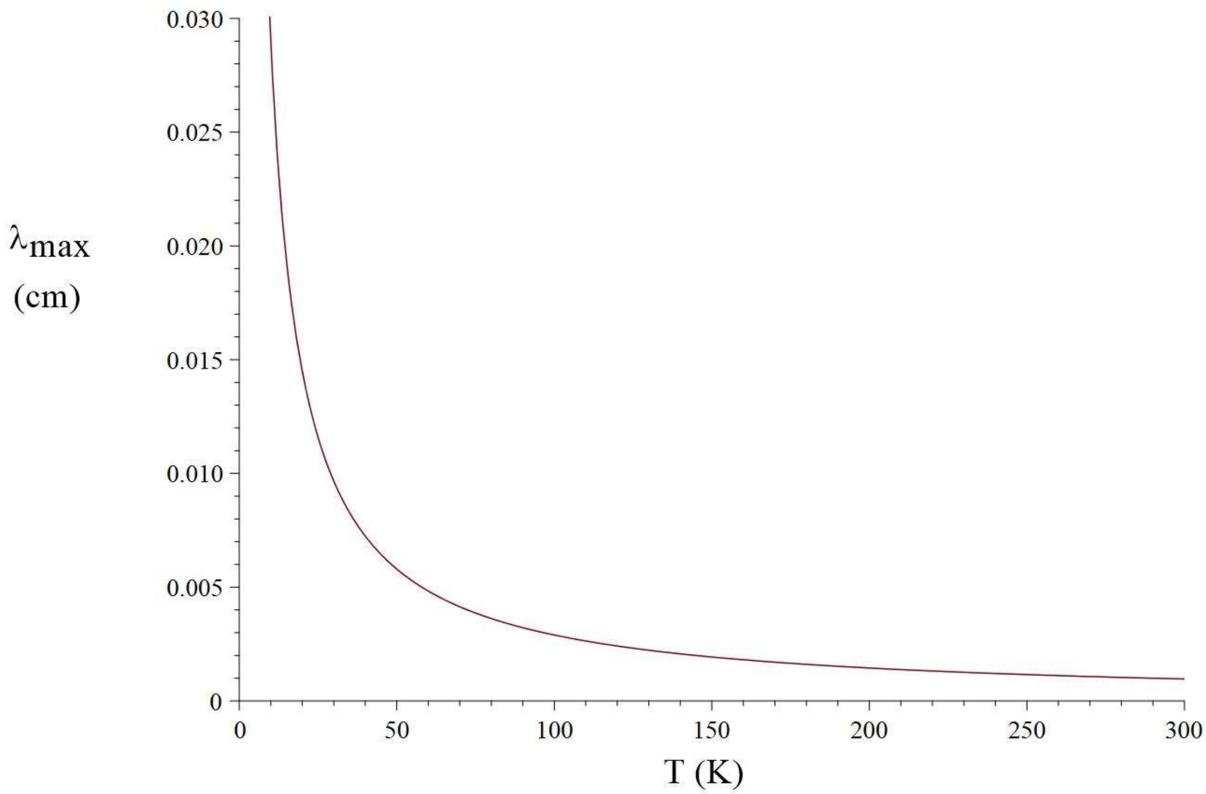
- Given the equation/graph for how a physical property depends on temperature, deduce the value of that property from the temperature or the temperature from a value of this physical property.
- Given the form of the relationship between temperature and some property (e.g. a linear relationship), come up with the equation or graph that describes this given enough data (e.g. two data points in the case of a linear relationship).

For all questions, explain your work. Don't just write equations and give the answer.

Question 1: A transistor amplifier is an electrical circuit that takes some input electrical signal and produces an amplified (i.e. proportionally larger) signal at its output. Because of temperature-dependent properties of the electrical components in the amplifier, the gain (amplification factor) of a transistor amplifier may depend on the temperature. The gain for a certain amplifier at room temperature (20.0°C) is 30.0, where as at 55.0°C it is 35.2. What would be the gain at 30.0°C if the gain depends linearly on temperature over this range?

Math tip: A linear relationship between two quantities X and Y, means that for a change in X (which we usually call ΔX), the change in Y is given by $\Delta Y = m\,\Delta X$, where m is some constant. In the range of X where this linear relationship exists, we can write $Y = m X + b$. If we graph Y vs X, then m is the slope and b is y-intercept where the graph crosses the y axis.

Question 2: All objects emit electromagnetic radiation whose intensity for the different wavelengths depends on the temperature of the object. Physicists and astronomers often use measurements of this electromagnetic radiation to determine the temperature of an object. The wavelength λ_{max} at which the intensity of this "thermal radiation" is greatest is inversely proportional to the temperature i.e. given by an equation $\lambda_{max} = C/T$, for some constant C. The precise relationship is plotted in the graph on the next page. In 1965, microwave radiation peaking at λ_{max}= 0.107cm was discovered coming in all directions from space. To which temperature does this correspond? This is the ambient temperature of the universe, i.e. temperature that an object in outer space far from any stars will have once it comes to equilibrium. Where did this radiation come from? (To find the answer, look up what the 1978 and 2006 Nobel Prizes in Physics were given for.)



Question 3: A platinum resistance thermometer is a device that allows us to determine the temperature by measuring the resistance of a piece of pure platinum wire. In the interval between the freezing point of water and 700.0°C, the relationship between the resistance and the Celsius temperature T_C is accurately captured by the formula

$$R = R_0 (1 + A\, T_C + B\, (T_C)^2)$$

where A and B are constants determined by measurements at the ice point of water, the steam point of water, and the melting point of zinc (419.514°C). (a) If R equals 10.000 ohms at the ice point of water, 13.946 ohms at the steam point of water, and 24.174 ohms at the melting point of zinc, find R0, A, and B (b) If the resistance is measured to be 17.7 ohms, what is the temperature? (c) Plot R versus T_C in the range from 0°C to 700.0°C.

Math tip: When we have several equations for several unknown variables, we can use the first equation to solve for one of the variables in terms of the others and then replace that variable in the remaining equations with this new expression. Or we can add/subtract equations with different coefficients to get a simpler equation where one or more of the variables has been eliminated.