Physics 103b

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Order of Magnitude Physics

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Problem Set 8

Due at *beginning* of class *4 March 1997*

Homework Problems:

1. On one side of a 1-cm thick glass pot is a high-tech hotplate with an adjustable temperature. On the other side is water kept by boiling at a constant 373K. Below some hotplate temperature T_x most of the heat will be transferred through the glass by conduction, but above T_x the heat will mostly be carried by radiation. Estimate T_x.

   Hints: the absorption length for electromagnetic radiation in glass is $\gg 1\,\mathrm{cm}$ at $\lambda < 4\mu\mathrm{m}$, and $\ll 1\,\mathrm{cm}$ at $\lambda > 5\mu\mathrm{m}$. In water, the absorption length is $\gg 1\,\mathrm{cm}$ at $\lambda < 1\mu\mathrm{m}$, and $\ll 1\,\mathrm{cm}$ at $\lambda > 2\mu\mathrm{m}$.

2. Estimate, using the principles of atomic absorption, the amount of dye needed to turn Millikan pond bright green. Typical dyes consist of two to five benzene rings with various small attachments to adjust the frequencies of electronic states and to make them soluble in the solvent of choice.

3. The upper 3/4 of piano strings are bare steel wires, stretched to the yield point of steel.
   a) Estimate the speed of transverse waves on such a piano string, and compare to the speed of sound in air.
   b) Estimate (using only the properties of steel) the length of a piano string whose fundamental frequency ν_1 is middle C (262Hz).

4. During an orchestra concert, heat generated by the players, stage lights and the audience causes the temperature in the auditorium to rise by 5°K. Assuming the players take no corrective action,
   a) Estimate the fractional change in frequency of notes played by the wind instruments. Do the frequencies of their notes go up or down as the temperature rises?
   b) Estimate the fractional change in frequency of notes played by the string instruments. Do the frequencies of their notes go up or down as the temperature rises? [hint: the coefficient of thermal expansion of spruce wood (used for piano and violin face and back plates) along the grain (which is parallel to the strings) is about 1/7 that of steel (used for strings).]

5. Boiling Water And Whistling Tea Kettles
   a) It takes about 5 minutes to bring a liter of water to a boil on a kitchen stove.
      i) How much *power* is being absorbed by the water?

ii) At what rate does the boiling water evaporate?

b) Many tea kettles come with whistles. The basic whistle is a hole of radius $\approx 0.15\,\mathrm{cm}$ through which water vapor can exit the kettle.

i) At what velocity does water vapor exit the hole when water is boiling inside the kettle?

ii) What is the Reynolds number of the flow near the hole?

iii) Why does the kettle whistle and what determines its frequency?

iv) Which multipole dominates the acoustic radiation? Estimate the acoustic power.

6. Invent a problem of your own.