Stefan-Boltzmann law for radiation

Aim: To show that the power radiated by an area is proportional to T^4.

Subjects: 4B40 (Radiation)

Diagram:

Equipment:

- Electric hot plate.
- Radiation sensor (thermopile).
- Measuring amplifier.
- Temperature sensor.
- Heat-conducting compound.
- Interface and data-acquisition system (we use PASCO ScienceWorkshop).
- Beamer to project monitor screen.

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Presentation: <u>Preparation.</u>

The temperature sensor is pressed to the hot plate using the spring/clamp mechanism (see Diagram). There is heat-conducting compound between the temperaturesensor and plate. The radiationsensor "looks" at an area close to the temperaturesensor.The software of the data-acquisition system is prepared to measure, every second: radiation (P), as a voltage and temperature. Four graphs are displayed simultaneously on the monitorscreen: Radiation as a function of T(K), $T^3(K^3)$, $T^4(K^4)$ and $T^5(K^5)$ respectively. Also a digital display reading temperature in ^oC is added to the screen.

<u>Presentation</u>

The electric hot plate is switched on, <u>on its lowest setting</u>. The digital temperauremeter shows the rising temperature of the plate

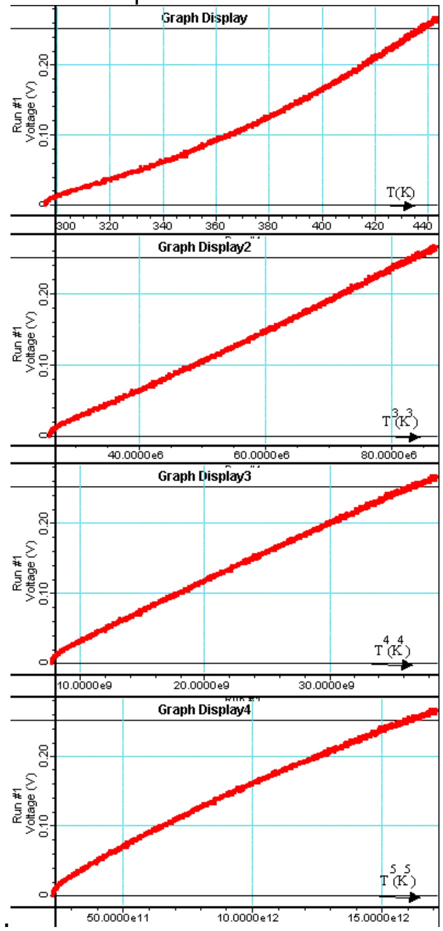

Figure 1

As soon as the temperature of the plate reads about 30^{o}C, the data-acquisition system is started to record temperature- and radiation measurements. Slowly temperature rises and the teacher can go on with his lecture. It takes about 30 minutes to reach a temperature of 150^{o}C. So, near the end of the lecture the data-acquisition is stopped and the heating of the plate switched off. Studying the four graphs it is clear that the

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T^4-graph is the straightest line among the four (see Figure1), so this is the best P-T relationship. (T^3-graph "curves" upwards and T^5-graph "curves" downwards.)

Explanation: We can obtain the Stefan-Boltzmann radiation law by integrating Planck's radiation law over all λ.

Remarks:

- Do not start measurements directly after switching on the hot plate. Heat capacity of the system makes that at the very beginning, temperatures in the system are not equally distributed. That's why we start measurements from 30°C on. (In Figure1 you can see this "switching-on"-effect in the graph at the leftside of the vertical Voltage-axis.)
  This is also the reason why the plate should heat up slowly, otherwise measured temperature and measured radiation are not related properly.
- The software also enables to apply a linear fit on the graphs recorded. This also shows that the T^4-graph has the closest approach to such a linear relationship (lowest chi^2).

Sources:

- Mansfield, M and O'Sullivan, C., Understanding physics, pag. 270-272
- Young, H.D. and Freeman, R.A., University Physics, pag. 1256-1258