Project: Heat flux calculation

E-mail submission to: m.rack@fz-juelich.de
Submission deadline: 31 October 2018. 11:59 p.m.

Criteria:

The final mark for the course "Scientific data analysis and modelling" will be defined by the successful completion of a programming project. As usual, 50% success are required to reach the mark "ausreichend" (4.0), 55% correspond to (3.7), ..., and finally 95% or better correspond to "sehr gut" (1.0).
Your program will be evaluated based on the following criteria (each criteria will have a different impact on the final mark).

- The result of the submitted program will have the strongest impact on your mark (up to 70%). It will be evaluated whether you program executes without any errors and fulfils the requirements as stated below.
- The second-most important aspect is a sufficiently documented code (up to additional 20%). Your comments within the code need to allow everyone – who knows the basics of coding – to read, understand, and extend your program.
- Finally, the performance/speed of your program is important (the final 10%). Your program will be checked whether or not it could be speeded-up by usage of Python's features also including standard packages like NumPy, SciPy, etc. (If I manage to speed-up the program by a factor of (a) 10 or more, 0% will be granted for this criteria, (b) between 5 (included) and 10, 5% will be granted, and (c) less then 5, 10% will be granted.)

Project description:

A typical difficulty in fusion research is that one needs to know the surface heat flux q_s onto an object but the available experimental measurements only provide the surface temperature T of the object, measured by infra red cameras. Therefore, it is required to solve the heat diffusion equation

$$\rho c_\mathrm{p} \frac{\partial T}{\partial t} - \nabla \cdot (\kappa \nabla T) = \dot{q}_\mathrm{V}$$

to know the heat distribution within the material. Here, ρ is the mass density of the material, c_p is the specific heat capacity, κ is the thermal conductivity, $\dot{q}_\mathrm{V}$ is the volumetric heat flux. Based on the heat distribution within the material one can calculate the heat flux onto the object

$$q_\mathrm{s} = -\kappa \left.\frac{dT(x)}{dx}\right|_\mathrm{s} ,$$

with x being the direction into the material and $\cdot|_\mathrm{s}$ describes the operation at the surface boundary. Consider a constant thermal conductivity, constant mass density, constant specific heat capacity, and no volumetric heat flux inside the material.
Write a program that solves the heat diffusion equation in two-dimensions (along the surface of the material and into the material) and calculates the heat flux onto a Tungsten object. The provided file[1] `TemperatureProfile.dat` contains the temperatures (in °C) for different times and (radial) locations along the surface. The time axis (in s) is given in `TemperatureProfile_time.dat` and the file `TemperatureProfile_position.dat` provides the radial coordinates (in m). The initial temperature distribution in the material can be considered as a linear decrease from the surface temperature at the first time slice down to 80 °C at a depth of 10 cm. Keep the total depth of your object flexible to enable tests on the impact of this geometrical aspect of the system. Stick to a fixed temperature of 80 °C at that location.

[1] See `https://fz-juelich.sciebo.de/s/IOEtGib8Hk8TaTj`. The other files are for comparison of your results.