# Seminar 2: Heat Convection with DRUtES

Transport of contaminants in porous media
Applied Hydropedology

## 1 Background

Heat flow is important in the soil. To simplify, we're assuming heat flow through a wall. We test different insulation materials by assigning different heat capacities and thermal conductivity values of several real-world materials. We will use

1. Stone concrete
2. Sand stone
3. Cotton

We use the heat equation, which for a one-dimensional problems states as

$$C\frac{\partial T}{\partial t} = \kappa_T \frac{\partial^2 T}{\partial x^2}, \tag{1}$$

where $C$ is the volumetric heat capacity [J.K$^{-1}$.L$^{-3}$], $T$ is the temperature [K], and $\kappa_T$ is the thermal conductivity [W.m$^{-1}$.K$^{-1}$].

## 2 Preparation

For this we will use

- Virtual Machine with Linux installation: Ubuntu mint
- Terminal and GitHub
- Texteditor Geany
- Open Source solver DRUtES

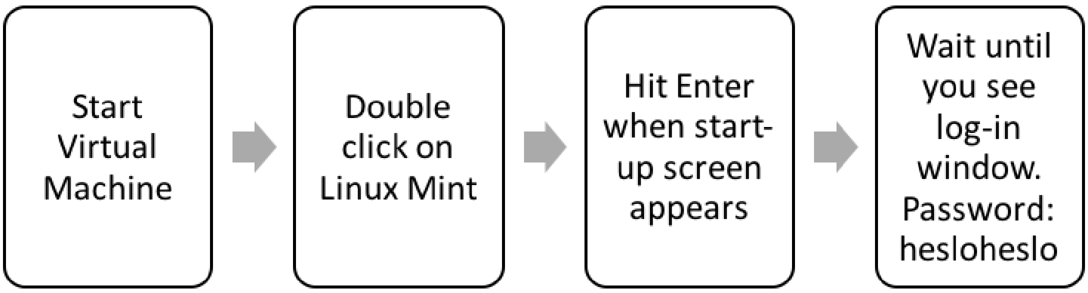


Figure 1: Start Linux on the the University computers

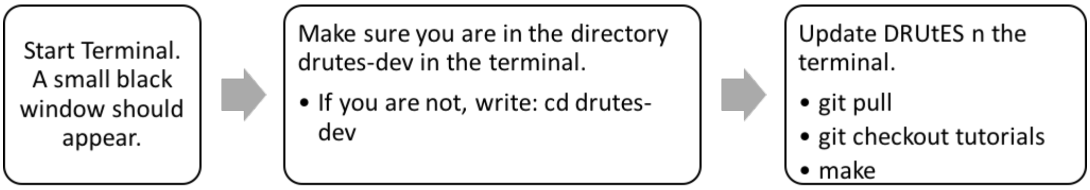


Figure 2: Start terminal and update DRUtES using git


Figure 3: Start geany to change the configuration files

## 3 Simulations

For all scenarios, we assume that the wall is between a heated room, which is maintaining a constant temperature of 20 °C, and the outside world during winter, which for the sake of simplicity is at a constant temperature of 0 °C.

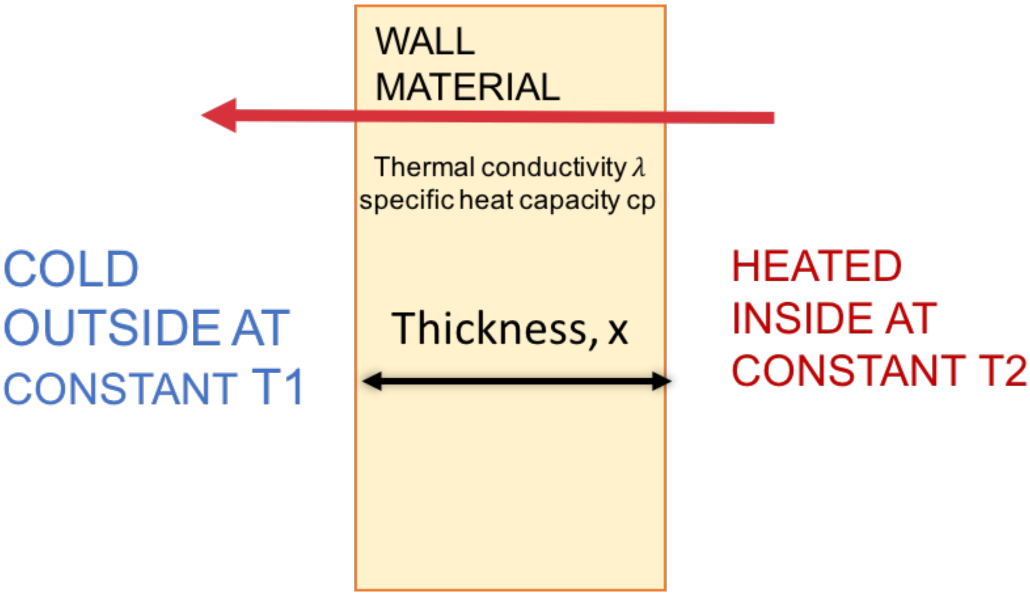


Figure 4: Simple heat conductivity through a wall

The outside temperature and the heated room temperature are our boundary conditions. They define the limits of our spatial domain. They give us a lot of information on our problem. We already know the solution of our problem at the boundaries and they do not change over time. This type of boundary condition is called **Dirichlet boundary condition**. We assume 1D flow. This means that we are only interested in one-direction. Although this might seem drastic, it only means that the other directions are homogeneous and do not provide us with more information.

We can assume a simple domain set-up as in Fig. 5. What is missing is the material properties defining

Table 1: Material properties needed for scenarios.

| Material | specific heat capacity $C_p$ [J kg$^{-1}$ K$^{-1}$] | density $\rho$ [kg m$^{-3}$] | thermal conductivity $\kappa_T$ [W m$^{-1}$ K$^{-1}$ ] |
|---|---|---|---|
| Stone concrete | 750 | 1400 | 1.7 |
| Sand stone | 920 | 2800 | 1.7 |
| Cotton | 1340 | 1550 | 0.04 |

the heat conduction. These can be found in Tab. 1 for three different materials: stone concrete, sand stone and cotton.

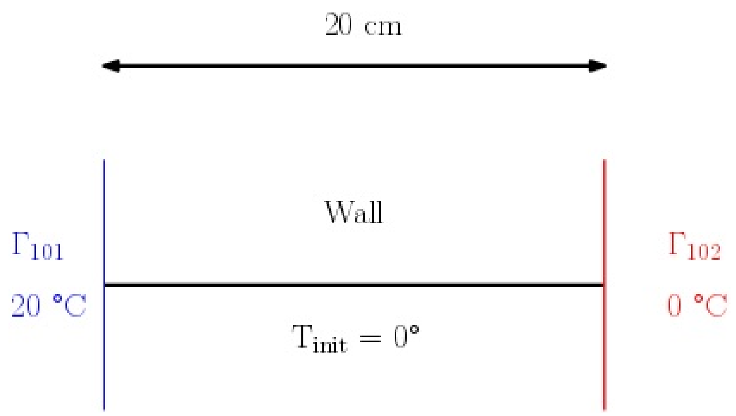


Figure 5: Domain set-up for 1D heat conduction through a wall with two constant Dirichlet conditions.

### Run simulations

To run the simulation with DRUtES, go back to the terminal window and write **bin/drutes** and hit enter

### Visualizing results

We prepared an R script to visualize the simulation. Go to the terminal and execute:
`Rscript drutes.conf/makeplot -name writename`
`writename` should be meaningful such as 'sandstone' or 'cotton'

# 4 Tasks

Follow the tutorial and answer following questions for all of the **3 materials**:

1. How long does it take for the temperature distribution to become linear within the wall?
2. How large is the steady state heat flux through the wall? Hint: The constant heat flux value $\phi_p$ can be calculated using the equation:
$$\phi_{\mathrm{p}} = -\kappa_T \frac{\mathrm{d}T}{\mathrm{d}x}.$$
3. Let's assume a wall area of A=15 m$^2$. Use the observation point at the boundary between the wall and the inside of room. How large was the cumulated heat loss after 24 h. How much will be lost after 48 h when the set-up does not change?