CHME 6011 - Advanced Transport Phenomena ©

CHME 6011 Term Project List

Project 1: Realistic temperature profile of the ground and freezing line

Find realistic temperature versus time data of a region with cold winters, ideally on an hourly basis, for a period spanning an entire winter.

Use this data as the boundary condition of a numerical simulation of the temperature profile of the ground. Emulate freezing by adding a sharp Gauss curve to the specific heat data, and account for the fact that the thermal properties of ice are different from the thermal properties of liquid water. Use a function to soften the step between liquid properties and ice properties.

Test the accuracy of the numerical procedure by using different grid spacings, and different parameters in the Gauss curve and the step function.

Make simulations of the temperature profile in the ground all winter. Make plots of temperature profiles at different times, temperature versus time plots at different depths, and freezing line versus time.

Comment on the contribution of diurnal temperature cycle and cold spells on the depth of the freezing line.

Project 2: Pollution plume downwind of a busy road

Use emission factors of vehicles to calculate the amount of an air pollutant (e.g., NO_x of fine particulate matter) emitted on a busy road. Make an assumption about the distribution of the emission (e.g., a rectangle with height 2 m and the width of the road).

Develop a model of the transport of the pollutant downwind of the road. Use a finite-difference scheme in the vertical direction and solve the resulting set of ordinary differential equations. Assume that the wind direction is perpendicular to the road and assume a realistic windspeed profile, and a realistic profile of the turbulent diffusivity. Assume that the pollutant transfer mechanism is by advection in the horizontal direction (in the direction of the wind) and by turbulent diffusion in the vertical direction.

Calculate the concentration of the pollutant at different distances from the road, and at different heights. Make plots of the concentration profiles.

Explore the effect of windspeed on the concentration profile.

Project 3: Cooling of a computer chip

Develop a 2D model of heat production and dissipation in a chip. Develop two model variants: one with cooling fins, and one without cooling fins.

Assume a rectangular chip that produces the heat. Assume that the chip is surrounded by a conducting material, either in the shape of a rectangular frame (no cooling fins) or a rectangular frame with rectangular extensions all around. Assume a convection heat transfer boundary condition.

Develop a 2D finite difference scheme to solve the problem. Test the effect of grid resolution on the result and assure that the grid resolution is sufficient to capture the process with sufficient accuracy.

Explore the effect of the size of the frame on the temperature distribution in the absence of cooling fins. Next, explore the effect of the size and shape of the cooling fins on the temperature distribution. Make figures of the temperature profiles.

Is the temperature profile sensitive to the thermal conductivity of the metal enclosure (e.g., iron vs. copper)? How critical is material selection?

Project 4: Light emission by an incandescent light bulb

The light emission mechanism of an incandescent light bulb is blackbody radiation of the wall of a cylindrical conductor that is heated by dissipating electrical energy.

Develop a simulation model of a cylinder heated from within, and with a blackbody radiation boundary condition. Bear in mind that the heating source is alternating current. Test your model with different grid spacings to ensure that the result is accurate.

Explore different sizes and energy dissipation rates. Find a combination that matches the time-averaged light spectrum and time-averaged efficiency. Is there a unique combination or are there multiple combinations that lead to the same outcome?

Make plots of the time-dependence of the temperature profile in the wire, and the light intensity. Is a steady periodicity obtained right away, or are many cycles needed to reach a steady periodicity? Is the light output strongly time-dependent or not?

What is the length of wire needed to obtain a 100-watt light bulb with realistic properties?

Project 5: Temperature profile of a small celestial body

A small celestial body is in a circular orbit around the sun and is tidally locked (i.e., it always shows the same side to the sun). Assume that the object has a simple shape (e.g., cylidrical), with one long dimension and two short dimensions (e.g., 1 m diameter for a cylinder) so that the object can be modeled as two-dimensional.

Use the light intensity of the sun and the angle of the surface of the object to the sun to calculate heat transfer from the sun to the object. Assume that the part of the surface that does not face the sun receives zero heat. Assume that the object is a blackbody and use the Stefan-Boltzmann law to calculate heat loss by the surface as a function of surface temperature.

Use a finite difference grid to discretize the problem (e.g., two cylindrical coordinates in the case of a cylinder) and solve by numerical simulation. Try different grid resolutions to ensure that the calculation is reasonably accurate.

Compare a rocky object with a metallic object, and/or evaluate the effect of size of the object on the temperature profile.

If time permits, you can consider a slow rotation and calculate the effect on the temperature distribution.