**Western University, Department of Mechanical and Materials Engineering**

**MME 9710: Advanced CFD**

Assignment 2: Introduction to One Dimensional Transient Analysis

**Submitted By:** Alexander K. Kiar, 250731557

**Submitted To:** Dr. Straatman

**Date:** June 1st, 2017

Table of Contents

[1. Discretization Methods 3](#_Toc485041100)

[2. Problem 1 3](#_Toc485041101)

[4. Problem 2 3](#_Toc485041102)

# Fortran Solver

Before completing the assignment problems, the Fortran code built for one dimensional diffusion and transient analysis was updated to include routines for advection problems. The updated code includes various subroutines to calculate each component of the advection discretization. The following sections outline the discretization method and the changes made to each subroutine of the solver. Printouts of the updated code can be found in Appendix 1.

## Advection Discretization

The advection problem adds a second heat flux through each control volume face (see Figure 1). In each problem the flow field is known. The convective heat flux is given by , and the diffusive flux is given by in the equations below.



Figure : Advection geometry

The inclusion of a convective term requires the discretization of both the mass and energy transport equations. The 1D mass equation is given by:

The 1D energy equation is given by:

The energy equation is integrated over a control volume and time step giving the following discretized equation:

Where it is assumed that:

To guarantee that mass is conserved over each control volume and remains independent of temperature level, the conservation of mass equation is multiplied by a reference temperature (assumed to be ), and subtracted from the energy equation. The discretized mass equation is derived by integrating over a control volume and time step giving:

Multiplying the above equation by and subtracting it from the energy equation gives:

If explicit time integration is assumed for both convection and diffusion, multiple restrictions are placed on the time step and control volume sizes. These restrictions stem from the assumption that the temperatures on the East and West faces of each control volume are derived from the central diffusion scheme, where and are given by:

To avoid these restrictions, an implicit scheme is implemented, changing the energy equation to:

This formulation allows for very large time steps, but still restricts the size of the control volumes due to the CDS temperature approximation. To remove this restriction, the unwinding scheme was implemented. The UDS scheme was used to remove the control volume restriction for all ranges of Peclet number. The Peclet number is given by:

The Peclet number measures the ratio between convective and diffusive heat transfer. The CDS approximation is only valid for Peclet numbers close to zero, where diffusion dominates the problem. This is because pure diffusion is linear, and the temperature on a control volume face can be approximated as the average of the temperatures between two control volumes centers. The UDS scheme removes this restriction because it carries the temperature from the previous control volume through the domain, which reflects the physical process of fluid flow.

The UDS scheme is given by:

Where is a weighting factor based on the direction of flow. Using the UDS scheme, the discretization becomes:

Where each coefficient is given by

This discretization ensures that all ranges of Peclet number can be modelled while keeping each coefficient positive.

## main.f

No major changes were made to the main routine. The only modifications made were call lines to the various subroutines required for the implementation of the advection scheme.

## inital.f

# Problem 1

# Problem 2