Homework 3: Dataflow Analysis and Project Work

In this homework you will learn more about dataflow analysis and also work on your semester project.
The project portion of this homework is intended to be done in your project groups. Be sure to follow the process described in the course's grading policy if you work in groups.

1. (10 points) [Concepts] [Calculate] [Semantics] Let $L = (L, \sqsubseteq)$ be a partially-ordered set. Suppose functions $f, g : L \to L$ are monotone. By definition (see appendix A.1 of our text [4]), a function $h : L \to L$ is *monotone* if and only if
$$\forall l, l' \in L : l \sqsubseteq l' : h(l) \sqsubseteq h(l'). \tag{1}$$
Prove that $f \circ g$ is also monotone.
In your proof use a calculational style (as in the handouts we provide in class [1, Section 4.2] [2, Chapter 4], see also Gries's article in *CACM* [3]), in which you justify each step.
(If you want to use LaTeX for solving such problems, you might like to use the macros we provide for calculational proofs and program analysis. These can be obtained from `http://refine.eecs.ucf.edu/gf/project/tex-include/scmsvn/` by browsing into the folders: trunk, then texmf, then tex, then latex, then misc; then the files you want are `calculation.tex`. You are welcome to use any other macros there as well.)

2. (10 points) [Concepts] [Semantics] According to our textbook [4], when using Chaotic iteration to find a solution for the Available Expressions analysis (in Section 2.1.1), one should start with a tuple in which each element is $\mathbf{AExp}_\star$. This problem is about creating an example to show why that is necessary.
Create an example program in the WHILE language for which the Chaotic iteration of the function that represents that program's Available Expressions analysis does not get the right result, if the iteration starts with $\vec{\emptyset}$. (Hint: the next part of this problem will be easiest if your example is very small.)

3. (10 points) [Concepts] [Calculate] [Semantics] Show how the Chaotic iteration for your example in the previous problem gives the right result for the Available Expressions analysis, if you start the iteration with a tuple in which each element is $\mathbf{AExp}_\star$. This should be expressed in the form of a calculation.

4. (10 points) [Concepts] [Calculate] [Semantics] Give an example program in the WHILE language in which the chaotic iteration for the Very Busy Expressions analysis (of section 2.1.3) does not give the right result, if the iteration starts with $\vec{\emptyset}$. To demonstrate your answer is correct, show what happens using chaotic iteration for that example with initial value $\vec{\emptyset}$.

5. (10 points) [Concepts] [Semantics] What property of an analysis, in general, determines what starting value is appropriate for iterations used to find a solution?

6. (20 points) [Concepts]
Do exercise 2.3 on page 135 of our textbook [4].

7. (150 points) [Concepts] [BuildTools] Write and test one static analysis for your semester project. Turn in enough so that we can understand what you have done. Appropriate documentation, with an overview and/or comments, will be helpful. Hand in your source files (but no generated files!).
You can use our WHILE language project as a starting point. The Unix command for cloning the project from github.com is:

```
git clone https://github.com/leavens/WhileLang.git
```

In Eclipse, use the "File" menu, then select "Import ...", the select "Git" then "clone URI" and use the URI `https://github.com/leavens/WhileLang.git`.

References

[1] Ralph-Johan Back and Joakim von Wright. *Refinement Calculus: A Systematic Introduction*. Graduate Texts in Computer Science. Springer-Verlag, Berlin, 1998.

[2] Edsger W. Dijkstra and Carel S. Scholten. *Predicate Calculus and program semantics*. Springer-Verlag, NY, 1990.

[3] David Gries. Teaching calculation and discrimination: A more effective curriculum. *Communications of the ACM*, 34(3):44–55, March 1991.

[4] Flemming Nielson, Hanne Riis Nielson, and Chris Hankin. *Principles of Program Analysis*. Springer-Verlag, second printing edition, 2005.