PRIFYSGOL CYMRU; UNIVERSITY OF WALES

DEGREE EXAMINATIONS JANUARY 2002

SWANSEA

Computer Science

CS 216 Theory of Programming Languages

Attempt 2 questions out of 3

Time allowed: 2 hours

Students are permitted to use the dictionaries provided by the University through the invigilators

January 2002

CS _216. THEORY OF PROGRAMMING LANGUAGES

(Attempt 2 out of 3 questions)

Question 1

(a) What is a *formal language L*? Define the *recognition problem* for the language *L*. Define the mathematical concept of a *grammar G* and how it defines a formal language *L(G)*.

[5 marks]

(b) Explain how grammars are used in the definition of programming languages. What are modular grammars and how can they assist in the definition of programming languages?

[5 marks]

(c) Define the concept of a *context-free grammar*. State the *Pumping Lemma* for context free grammars. Give an example of a property of a programming language that cannot be defined by any context-free grammar. Sketch the mathematical method used to prove such facts.

[10 marks]

(d) Give a context-free grammar that defines *one* of the following

(i) postal addresses for a country of your choice;
(ii) file name formats for an operating system of your choice;
(iii) addresses for a type of URL of your choice.

[5 marks]

Question 2

(a) Define carefully the mathematical concept of a (*many sorted*) *signature*. What aspect of a data type does a signature model?

[4 marks]

(b) Give a context-free grammar that defines the syntax of a language for defining all signatures.

[5 marks]

(c) *Sketch briefly* how to define the semantics of the **while** language over all signatures.

[7 marks]

(d) Show how to extend the grammar for the language of signatures given in part (b) to define the language of signatures that can **import** other signatures by name from a library of signatures.

[2 marks]

Explain, using an example,

(i) how the **import** construct introduces a modular and hierarchical structure to signatures.

[2 marks]

(ii) how this modular and hierarchical structure is removed by *flattening*.

[2 marks]

(e) The **while** language over all signatures *with* **import** WP_1 is an example of a complex extension to the simpler kernel language of the **while** language over all signatures (*without* **import**) WP_0. *Sketch briefly* how flattening may be used to define a semantics for the language WP_1 from the semantics of WP_0 given in part (c).

[3 marks]

Question 3

(a) Let Σ be a many sorted signature. Define carefully the concept of a (*many sorted*) Σ-*algebra*. What aspect of a data type does an algebra model?

[4 marks]

(b) Give a signature Σ for the integers and an example of a finite Σ algebra. Does your example satisfy the same laws as the standard model of the integers?

[5 marks]

(c) Let A and B be Σ-algebras. Define carefully the concept of a
(i) Σ-*homomorphism* $\varphi: A \to B$ and
(ii) Σ-*isomorphism* $\varphi: A \to B$.

Briefly, explain their role in the theory of data types.

[6 marks]

(d) Consider the following signature.

signature Machine;
sorts state, input;
operations next: state $\times$ input $\rightarrow$ state;
output: state $\times$ input $\rightarrow$ output
endsig

Let M and N be two Σ_{Machine} algebras modelling two machines. Let φ : M $\rightarrow$ N be a Σ_{Machine} homomorphism. Write down the homomorphism equations for φ.

[4 marks]

(e) Give Dedekind's axiomatic specification (Σ, T) of the natural numbers. Explain how it captures precisely the abstract data type of natural numbers.

[6 marks]