**Application for Quantitative Reasoning designation for Introduction to Semantics**

**Course description:**
Introduction to Semantics: This course serves to introduce a recent generative framework for the interpretations of sentences of natural language through semantic composition. We begin by familiarizing ourselves with various formal analytical tools grounded in logic and mathematics including: set theory, relations, functions, functional application, statement logic, predicate logic, lambda abstraction, and type theory. We then turn to the application of those tools to core phenomena of interest in theoretical semantics: modification, variable biding, quantification, scope, and ellipsis.

**Retroactive Approval:**
Yes, we are seeking retroactive approval for the course for the current semester (Fall 2017) only.

**Response to QR criteria:**

**1. Interpret data represented in a variety of ways, such as graphs, tables, and charts. How is this met?**

Students must both generate and interpret data presented in truth tables, phrase structure trees, set theoretic statements/diagrams and lambda notation. They must also show ability to convert data presented in one format into another (e.g to convert a law demonstrated in set theory into a propositional logic truth table; to convert an expression in set theory to an expression in terms of functions). Examples can be found below in A1.

**2. Solve problems, through the use of patterns, numbers, and symbols. How is this met?**

The core enterprise of semantics as it is currently practiced is to provide a formal interpretation for sentences of natural languages using mathematical functions. Students must learn to analyze predicates of natural language (e.g. a transitive verb like *see*) as right-to-left schönfinkelized (curried) functions (examples in A2) as expressed using lambda abstraction. They must learn formal methods of composing nodes in a binary branching phrase structure tree, such as functional application and predicate modification (defined in A2). Each week they are presented with ever more complex expressions of natural language which require analysis using these formal tools.

**3. Evaluate the value and validity of provided information. How is this met?**

In this course, students are consistently asked to evaluate the validity of solutions presented. They come up with cogent critiques of the solutions initially offered, which are often partial by necessity or for the purposes of parsimony. For examples, see prompt 5 as well, which addresses specific ways in which students are asked to try to formulate alternatives when information is inadequate. In the case of some advanced topics, I also prompt the students to articulate what seems wrong about the solution provided, even when we do not have the tools/techniques to improve upon it. For instance, in the analysis of adjectives like *former* the students must discover for themselves that a function of type <et, et> will be inadequate (proof in A3 below).

**4. Determine if the solution to a problem makes logical sense in the real world. How is this met?**

This is a constant process in semantics, since our object of analysis is natural human language. For instance, our initial denotation of the definite article *the* is as follows:
$[[\text{the}]] = \exists!x: f(x)=1, \iota y: f(y)=1$
This denotation would suggest that a noun phrase like *the football team at UVM* should fail to denote anything (since it doesn't exist), and thus a sentence like *The football team at UVM is excellent!* should have no truth value (is entirely uninterpretable). However, students are asked to interrogate their own intuition about this sentence and its negative alternative, *The football team at UVM is not excellent*! They tend to report that indeed these sentences do seem to have a truth value – the first returns 0 (false), while the second seems to return 1 (true). They must then reevaluate the presuppositional nature of the denotation proposed (and the way in which denotation failure is mapped onto truth values) based on their real-world intuitions about how we use and understand sentences of this type.

**5.Formulate alternative solutions. How is this met?**

It is in the nature of formal theoretical linguistics to press students to articulate cogent critique of the theory. For this reason, students in this class are often presented with natural language puzzles which the theory is ill-equipped to solve. They are then asked to modify or adapt their formalisms to become more empirically adequate, while keeping economy of mechanism as a core concern. For instance, in the 5th week of the course students are presented with the problem of non-intersective modification (while *a blue book* is a blue thing that is also a book, *a small planet* is not a small thing that is also a planet). Up until this point, students have been provided with the combinatory rule of Predicate Modification (in A2), which doesn't capture non-intersectivity for predicates of type <et> at all. They must decide how to provide a formal interpretation for non-intersectivity (that is, where to lodge the necessary increase in complexity). There are several possibilities, such as massive type ambiguity for adjectives, or type ambiguity for the copula (in A5 below). They must evaluate the alternatives, as well as the value of the combinatory rule that failed in the first place, to determine how to handle such scenarios. This is indicative of the method taken for problem-solving in the course as a whole.

**6. Communicate effectively the thought process used to interpret and solve the problem. How is this met?**

For each and every instance of problem solving, whether in class on the whiteboard or in writing on assignments and tests, students are asked to explain how they came to the response and to show all possible work or computation. In many cases, the reasoning process by which they approach a problem is as valuable or more valuable than the "correct" response to that question, as it will allow them to approach a new problem/question of a type not yet encountered successfully in the future. Model responses of the sort I expect/require can be found in the student homeworks (which are submitted weekly) and I can provide examples upon request.

**Examples:**
**A1**
HW1 question: In class, we discussed De Morgan's Law in terms of set theory: C-(A∪B) = C-(A∩B). Provide a proof of this equivalency using propositional logic in a truth table with two atomic variables.
Answer:

| p | Q | ¬p | ¬q | p v q | ¬(pvq) | ¬p ^ ¬q |
|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 |

**A2:**
HW 3 question: Provide a left-to-right and then a right-to-left Shönfinkelization of the relation *see* in the following universe:
$R_{see}$ = {<Loki, Beanie>, <Beanie, Melania>, <Melania, Donald> < Loki, Melania>, <Loki, Donald>, < Beanie, Donald>}
Then describe WHY we need to be able to do right-to-left Schönfinkelization in this case (why it is important for natural language interpretation).

Left-to-Right

L → L → 0
  B → 1
  M → 1
  D → 1
B → L → 0
  B → 0
  M → 1
  D → 1
M → L → 0

| | |
|---|---|
| | B → 0 |
| | M → 0 |
| | D → 1 |
| D → | L → 0 |
| | B → 0 |
| | M → 0 |
| | D → 0 |

<u>Right-to-Left</u>

| | |
|---|---|
| L → | L → 0 |
| | B → 0 |
| | M → 0 |
| | D → 0 |
| B → | L → 1 |
| | B → 0 |
| | M → 0 |
| | D → 0 |
| M → | L → 1 |
| | B → 1 |
| | M → 0 |
| | D → 0 |
| D → | L → 1 |
| | B → 1 |
| | M → 1 |
| | D → 0 |

Lambda denotation for this verb:
$[[\text{see}]]\ \lambda x.x\in D_e.\lambda y.\ x\in D_e.y$ sees x

Functional Application: If α is a branching node with daughters {β,γ}, and [[β]] is a function with [[γ]] in its domain, then [[α]] = [[β]] ([[γ]]).

Predicate Modification: If α is a branching node with daughters {β,γ}, and [[β]] and [[γ]] are functions of type <et>, then [[α]] = [[β]] = [[γ]] = 1

**A3:**
Proof that *former* is not of type <et, et>
If [[α]] = [[β]] and [[γ]] is a function <et,et> with [[α]] [[β]] in its domain, then [[γ]] ([[α]]) = [[γ]] ([[β]])
So if [[cat]] = [[domestic feline]] then [[small cat]] = [[small domestic feline]]
[[presidents of the USA]] = [[men]] BUT [[former presidents of the USA]] ≠ [[former men]]
∴ *former* is not a function of type <et, et>

**A5:**
Type ambiguity for adjectives and the verb *be*
$[[\text{gray}]] = \lambda x.x\in D_e x$ is gray (type <et>)
OR
$[[\text{gray}]] = \lambda f.\ f\in D_{et}.\ \lambda x.x\in D_e.\ f(x)=1$ and x is gray (type <et,et>)

$[[\text{be}]] = = \lambda f.\ f\in D_{et}.\ f$
OR
$[[\text{be}]] = = \lambda f.\ f\in D_{et,et}.\ \lambda x.x\in D_e.\ f(x)=1$