CS 603 Exam 2 **Spring 2006** **Name _____**

1. For each ML function definition below, write the type (usually a polymorphic type) that the ML interpreter would infer for the function. **[20 points]**

   a. fun f _ = [ ];

      fn : _____

   b. fun f (x,y) = (y,x);

      fn : _____

   c. fun f (x,y,z) = [x,y,z];

      fn : _____

   d. fun f (w,x,y,z) = (w div x, y/z);

      fn : _____

   e. fun f x y = let val g = op^ in g(x,y) end;

      fn : _____

   f. fun f (x,y,z) = z (y x);

      fn : _____

   g. fun f x y z = x y z;

      fn : _____

   h. fun f w x y z = if w then x else y=z;

      fn : _____

   i. fun f (w,x) = let fun g (y,z) = y (y z) in g (w,x) end;

      fn : _____

   j. fun f (u,[ ]) = [u] | f([ ],v) = [v] | f(w::x,y::z) = [w,y]::f(x,z);

      fn : _____

2. Write an ML function inner(X,Y,f,g) that returns the inner product of the lists X and Y with respect to binary operations f and g. Assume that lists X and Y are nonempty lists of the same length, and that operation f is associative. You may use helper functions if you wish. For maximum credit, do not call the predefined hd or tl functions. Example: inner([1,2,3], [4,5,6], op+, op*) should return 32, because 1*4+2*5+3*6 = 32. This kind of inner product is often called a dot product. Another example: inner([1,2,3], [4,5,6], op*, op+) should return 315, because (1+4)*(2+5)*(3+6) = 315. **[10 points]**

3. Write an ML function outer(X,Y,f) that returns the outer product of the lists X and Y with respect to binary operation f. You may use helper functions if you wish. For maximum credit, do not call the predefined hd or tl functions. The result is a list of length |X|, each of whose members is a sublist of length |Y|. The k^{th} element of the j^{th} sublist is obtained by applying operation f to the j^{th} element of X and the k^{th} element of Y. Example: outer([1,2,3], [4,5,6,7], op*) should return the list [[4,5,6,7],[8,10,12,14],[12,15,18,21]]. This kind of outer product is often called a multiplication table. Hints: Write a helper function that constructs one of the sublists. Also, consider using the map function. **[10 points]**

4. List five (or more) most significant ways that ML differs from Scheme. **[10 points]**

5. List five (or more) most significant ways that Smalltalk differs from C++ and/or Java. **[10 points]**

6. In μSmalltalk, a message sent to a receiver named super is implemented as a message sent to self, except that method search does not begin in the receiver's class as it normally would. Two proposed implementations of super are described below. If these two implementations are equivalent, then explain why both implementations always produce the same result. Otherwise provide an example that shows how the two implementations can produce different results. Also state which, if either, of these two implementations is correct. **[10 points]**

   a. Method search begins in the superclass of the receiver's class.
   b. Method search begins in the superclass of the class that defines the method that sends the message to super.

7. First read this μSmalltalk code. Next determine the values that would be obtained upon sending each of the messages {p, q, r, s, t} to each of the receiver objects {b, c, d, e, f, g}. Write these values in the table below, where each row corresponds to a message and each column corresponds to a receiver. **[15 points]**

```
(class A Object ( )
        (method p ( ) (q self))
        (method q ( ) (r self))
        (method r ( ) (s self))
        (method s ( ) (t self))
        (method t ( ) 1)
)
(class B A ( )
        (method p ( ) (s self))
        (method r ( ) 2)
)
(class C B ( )
        (method q ( ) (p self))
        (method s ( ) 3)
)
(class D C ( )
        (method p ( ) 4)
        (method t ( ) (r self))
)
(class E D ( )
        (method q ( ) 5)
        (method s ( ) (t self))
)
(class F E ( )
        (method r ( ) (q self))
        (method t ( ) 6)
)
(class G F ( )
        (method p ( ) (q self))
        (method r ( ) (t self))
        (method s ( ) 7))

(val b (new B))
(val c (new C))
(val d (new D))
(val e (new E))
(val f (new F))
(val g (new G))
```

	b	c	d	e	f	g
p						
q						
r						
s						
t						

8. Write a μSmalltalk class Queue such that each message send in the client would produce the output or return value as indicated below. **[20 points]**

```
(class Node Object (data next)
        (method data ( ) data)
        (method next ( ) next)
        (method data: (x) (set data x))
        (method next: (x) (set next x))
)
; definition of class Queue should go here
```

```
(val Q (new Queue))
(isEmpty Q)              ; <True>
(enqueue: Q #a)          ; a
(enqueue: Q #b)          ; b
(enqueue: Q #c)          ; c
(isEmpty Q)              ; <False>
(display Q)              ; a   b   c
(dequeue Q)              ; a
(dequeue Q)              ; b
(dequeue Q)              ; c
(isEmpty Q)              ; <True>
(dequeue Q)              ; nil
```