Problem 1 (9 points)

What is the result of the evaluation of the final statement in each of the following groups of Scheme expressions? Write “error” if an error would result or “procedure” if a procedure would be returned. Assume that each group is evaluated separately.

```
(define a 1)
(define b 3)
(define c 5)

(let ((a 2)
      (b (+ a 5))
      (c b))
  (+ a b c))
```

```
(define (map lst op)
  (if (null? lst)
      nil
      (cons (op (car lst))
            (map (cdr lst) op)))))

(map (lambda (x) (if (even? x) 1 0))
     (list 2 3 4 5 6 7))
```

```
(define (my-func f)
  (lambda (x y) (f (f x y) (f x y))))

((my-func *) 2 3)
```
Problem 2 (12 points)

a. Define applicative order evaluation

b. Define normal order evaluation

c. Given the following code,

```
(define (add a b)
  (display " plus ")
  (+ a b))

(add (begin (display " one ")
           1)
     (begin (display " two ")
            2))
```

Which of the following could be printed in Scheme? In normal-order Scheme?

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Normal-order Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>plus one two</td>
<td></td>
</tr>
<tr>
<td>plus two one</td>
<td></td>
</tr>
<tr>
<td>one plus two</td>
<td></td>
</tr>
<tr>
<td>two plus one</td>
<td></td>
</tr>
<tr>
<td>one two plus</td>
<td></td>
</tr>
<tr>
<td>two one plus</td>
<td></td>
</tr>
</tbody>
</table>
Problem 3 (12 points)

Assume the following Scheme expressions are evaluated sequentially. Fill in the table below, using `eq?`, `eqv?` and `equal?` to compare the items in the first two columns. You may find it useful to draw the box and pointer diagrams for this problem, but you are not required to do so.

```
(define a (list 1 2 3))
(define b (list 1 2 3))
(define c (list 4))
(define d (cons 4 a))
(define e (append c b))
```

<table>
<thead>
<tr>
<th></th>
<th>eq?</th>
<th>eqv?</th>
<th>equal?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cdr d)</td>
<td>(cdr e)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cdr d)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

```
Problem 4 (8 points)

For the two expressions below, write the sequence of cars and cdrs needed to get the number 3 out of each list. You may find it helpful to draw the box-and-pointer diagrams, but you will not be graded on them.

```
(define first-list (cons 1 (cons 2 (list 3 4 5))))
```

```
(define second-list (list (cons 1 2) (cons 3 4) 5))
```
**Problem 5 (15 points)**

Write a procedure that takes two ordered lists (low to high) and returns a list of the merged elements with no duplicates. For example,

\[
\text{(merge '(1 3 5 6) '(2 4 6 8 10 12))}
\]

will return the list

\[
(1 2 3 4 5 6 8 10 12)
\]

While you can assume that the lists are ordered, do not assume that the lists are equal lengths.

What is the order of growth of the \texttt{merge} procedure in terms of time and space?

Time: _________________________________

Space: _________________________________

What variable in the function is \texttt{n} dependent upon?

Does \texttt{merge} generate a recursive or an iterative process? __________________
Problem 6 (10 points)

Write a function apply-twice that takes a function $f$ as its argument and returns a function that takes one argument as input and returns the value that one would obtain if $f$ were applied twice to that argument.

For example,

$$((\text{apply-twice square}) \ 2)$$

would return

16

and

$$((\text{apply-twice (lambda (x) (+ x 2))) \ 5})$$

would return

9
Problem 7 (12 points)

Using the following procedure for dealing with trees,

\[
\text{(define (tree-manip tree init leaf first rest accum)}
\text{(cond ((null? tree) init)}
\text{((not (pair? tree)) (leaf tree))}
\text{else (accum}
\text{ (tree-manip (first tree) init leaf first rest accum)
\text{ (tree-manip (rest tree) init leaf first rest accum))))}
\]

write calls to perform the operations described below. Suppose that we provide a test tree,

\[
\text{(define test-tree ' (1 (2 (3 (4) 5) 6) 7))}
\]

Write the call to tree-manip that will compute the sum of the leaves of test-tree, resulting in a return value of 28.

\[
\text{(tree-manip ____________________________________________________________________}
\text{____________________________________}
\text{____________________________________}
\text{____________________________________}
\text{____________________________________}
\text{____________________________________)
}

Write the call to tree-manip that will flatten the test-tree, resulting in a return value of (1 2 3 4 5 6 7).

\[
\text{(tree-manip ____________________________________________________________________}
\text{____________________________________}
\text{____________________________________}
\text{____________________________________}
\text{____________________________________)
}
Problem 8 (16 points)

Despite the dot-com bust, Louis Reasoner has decided that he would like to create a web site to help people track their collections. The back end of the web site will be programmed in Scheme. First, we need to create a means for storing information about an item in a person’s collection: each item record will contain the name of the item, its estimated value, and its condition.

We define the constructor \texttt{make-item} as follows:

\begin{verbatim}
(define (make-item item-name value condition)
  (list (cons item-name value) condition))
\end{verbatim}

Write the selectors \texttt{item-name}, \texttt{item-value}, and \texttt{item-condition}.

To store all of the items in a person’s collection we will use the following constructor:

\begin{verbatim}
(define make-collection-list list)
\end{verbatim}

Write the selectors \texttt{first-item} and \texttt{rest-items}.
Problem 8 continued

Write a procedure called total-value which takes a collection-list and returns the total value of the collection. Be sure to use the constructors and selectors that you helped define on the previous page.

What is the order of growth of the total-value procedure in terms of time and space?

Time: _________________________________

Space: _________________________________

What variable in the function is n dependent upon?

Does total-value generate a recursive or an iterative process? ________________
Problem 9 (6 points)

Given the following definition of cons, define car and cdr.

(define (cons x y)
  (lambda (m)
    (cond ((eq? m 'car) x)
          ((eq? m 'cdr) y)
          (else (error "Unknown message – CONS” m))))