CMPSC 461: Programming Language Concepts
Midterm 2 Practice Questions

Use these problems in addition to Assignment 4, 5 and 6 to prepare for the 2nd midterm.

Problem 1 For each of the following Scheme programs, circle all `x`'s that refer to (i.e., are in the scope of) the definition of `x` at the FIRST LINE. You don't need to circle anything if no such `x` exists.

```
(let ((x 1))
   (let ((x 2))
     (+ x y)))
```

```
(let ((x 3))
   (let ((x 4) (y x))
     (+ x y)))
```

```
(let ((x 5) (y 6))
   (let* ((y x) (x y))
     (+ x y)))
```

Problem 2 What is the difference between static, stack, and heap allocation and how do they affect the lifetime of a variable?

Problem 3 What is a tail-recursive function? What makes it an interesting concept?

Problem 4 What outputs are produced by the following pseudo code if the language uses static scoping? What are the outputs if the language uses dynamic scoping?

```
a=2; b=3;
int f1(a){
  return a + b;
}
int f2(b) {
  return 2 * f1(b);
}
print f1(a) * f2(a);
```


Problem 5 Consider the following pseudo code.

```
int a=0;
void A(int m) {
  print a;
  m = a;
}
void main () {
  int a=1, b=2;
  A(b);
  print b;
}
```

1. What are the outputs if the language uses static scoping and all parameters are passed by value?
2. What are the outputs if the language uses dynamic scoping and all parameters are passed by reference?

Problem 6 Use the following typing rules to write down the proof tree for the term $((\lambda x : \texttt{bool} \,.\, (\lambda y : \texttt{bool} \,.\, x \wedge y))\ \texttt{true})$.

Typing rules: $\Gamma \vdash \texttt{true} : \texttt{bool}$ (T-TRUE) $\Gamma \vdash \texttt{false} : \texttt{bool}$ (T-FALSE) $\Gamma, x : \tau \vdash x : \tau$ (T-VAR)

$$\frac{\Gamma \vdash e_1 : \tau \to \tau' \quad \Gamma \vdash e_2 : \tau}{\Gamma \vdash e_1\ e_2 : \tau'}\ \text{(T-APP)} \qquad \frac{\Gamma, x : \tau \vdash e : \tau'}{\Gamma \vdash (\lambda x : \tau \,.\, e) : \tau \to \tau'}\ \text{(T-ABS)}$$

$$\frac{\Gamma \vdash e_1 : \texttt{bool} \quad \Gamma \vdash e_2 : \texttt{bool}}{\Gamma \vdash (e_1 \wedge e_2) : \texttt{bool}}\ \text{(T-AND)}$$

Problem 7 Follow the constraint unification rules in Lecture Note 4 to solve the following constraint

$$(\texttt{int} \to \alpha = \beta \to \beta; \beta = \texttt{int})$$