Programming Languages (CS 329) **Homework 2**
Computer Science and Engineering **Out: 2000-08-24**
Indian Institute of Technology Bombay **Due: 2000-10-05**

1. Complete the following denotational semantics for FLK!:

$$\begin{aligned}\mathcal{E}[\![\texttt{(begin } E_1 \ E_2\texttt{)}]\!] &= \underline{\quad\quad} \\ \mathcal{E}[\![\texttt{(write } E_{\text{loc}} \ E_{\text{nval}}\texttt{)}]\!] &= \underline{\quad\quad}\end{aligned}$$

2. Use the denotational definition of FLK! to interpret the following code:

```
(let r = (new 1)
    (begin
        (write r (+ 1 (read r)))
        (read r)  )  )
```

3. Desugar multi-parameter procedure declarations and invocations into single-parameter versions under (a) static and (b) dynamic scoping.

4. We have defined macros `HALF`, `DEC` and `EVEN?`. Using these, we are interested in determining if the binary representation of a number (given as a Church numeral) contains an even or odd number of ones. If we could use recursion directly, we could write this as:

```
EVEN-ONES? ≡ (λ  n (IF (ZERO? n)
                       TRUE
                       (IF (EVEN? n)
                           (EVEN-ONES? (HALF n))
                           (ODD-ONES?  (DEC  n)) ) ) )
ODD-ONES?  ≡ (λ  n (IF (ZERO? n)
                       FALSE
                       (IF (EVEN? n)
                           (ODD-ONES?  (HALF n))
                           (EVEN-ONES? (DEC  n)) ) ) )
```

We have seen in class that defining

```
FACT' ≡ (λ  f (λ  n (IF (ZERO? n) 1̄ (TIMES n ((f f) (DEC n))) ) ) )
```

and calling `((FACT' FACT')` $\bar{n}$`)` enabled us to implement recursion. Use a similar technique to eliminate recursion from the above procedures.

5. In implementing FLK!, we let

$$\begin{aligned} & \mathit{Store} = \mathit{Loc} \rightarrow \mathit{Value} + \mathit{Error}, \\ \text{not} \quad & \mathit{Store} = \mathit{Loc} \rightarrow \mathit{ExpVal} + \mathit{Error}. \end{aligned}$$

How would the interpreter know if the result of some computation is a *Value* or *ExpVal*? Is it necessary for the interpreter to know this?