1

Discuss the pros and cons of call-by-value and call-by-name semantics. [3]

Consider the syntax of the following pure functional language

$$
\begin{array}{lll}
e & ::= & n \mid \textbf{fn}\ x{:}T \Rightarrow e \mid e\ e \mid x \mid \Omega \\
T & ::= & \mathsf{int} \mid T \rightarrow T
\end{array}
$$

where the static and dynamic semantics of Ω are given by rules

$$
\text{(omega)} \quad \frac{}{\Gamma \vdash \Omega{:}\mathsf{int}} \qquad\qquad \text{(omega)} \quad \Omega \longrightarrow \Omega
$$

Give typing rules and CBN dynamic semantic rules for the other constructs. [6]

Give an expression that would behave differently in the CBV and CBN semantics, and give its final state in each (if any). [2]

For this language, the desired type preservation result would be of the form "If $\Gamma \vdash e{:}T$ and $e \longrightarrow e'$ then $\Gamma \vdash e'{:}T$". In proving that, a substitution lemma would be required. Give a statement and proof of that substitution lemma. [9]