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

Consider the syntax of the following pure functional language:

\[
\begin{align*}
e & ::= n \mid \text{fn} \ x:T \Rightarrow e \mid e \ e \mid x \mid \Omega \\
T & ::= \text{int} \mid T \to T
\end{align*}
\]

where the static and dynamic semantics of $\Omega$ are given by rules:

\[
\begin{align*}
(\omega) & \quad \Gamma \vdash \Omega: \text{int} \\
(\omega) & \quad \Omega \to \Omega
\end{align*}
\]

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 $e \to e'$ then $\Gamma \vdash e':T$”. In proving that, a substitution lemma would be required. Give a statement and proof of that substitution lemma. [9]