1. **First Principles:**
   Prove that $\log(n!) \in \Theta(n \log n)$ using first principles.

2. **Limit Rule:**
   Prove $(\log n)^2 \in o(n)$.

3. **Loop Analysis:**
   Analyse the following piece of pseudocode and give a tight ($\Theta$) bound on the running time as a function of $n$.

   ```plaintext
   k := 1
   for i from 1 to n:
     j := 0
     while j < n:
       j := j + k
     k := k * 2
   ```

4. **Challenge Question:**
   Prove Q1 using the limit rule.