A. Performance of the M/M/1 queue with varying arrival and service rates:

1. **Plot #1:** plot the average number of customers \((N)\) and the average time \((T)\) spent in the M/M/1 queue with service rate \(\mu = 1\) and arrival rate \(\lambda \in (0, 1)\), versus the utilization factor \(\rho = \lambda / \mu\).

2. Assume that in another M/M/1 queue the arrival rate and the service rates are \(K > 1\) time larger, i.e., \(\lambda' = K\lambda\) and \(\mu' = K\mu\). **Plot #2:** plot the average number of customers \((N'(K))\) and the average time spent in the queue \((T'(K))\), versus the utilization factor \(\rho' = \lambda'/\mu'\). Perform the experiment for \(K = 2, 10\).

3. Explain any difference of the plots #1 and #2.

4. Is \(K\) affecting the average service time? If so, how?

B. Comparison of fixed and statistical multiplexing:

1. **Plot #3:** plot the average time \((T)\) spent by a customer in a system of \(m\) M/M/1 queues, each queue with service rate \(\mu/m\) and arrival rate \(\lambda/m\), versus the utilization factor \(\rho \in (0, 1)\). Perform the experiment for \(m = 2, 10\), keeping always \(\mu = 1\).

2. The system in B.1 represents a fixed multiplexing system, in which each one of the \(m\) customer flows arrives at rate \(\lambda/m\) and is processed by a M/M/1 queue with rate \(\mu/m\). The system in A.1 represents a statistical multiplexing system, in which \(m\) customer flows arrive at rate \(\lambda/m\) and they are multiplexed together into a single flow of rate \(\lambda\), and processed by a single M/M/1 queue with service rate \(\mu\). **Plot #4:** Compare the average time \((T)\) spent in a fixed multiplexing system and in a statistical multiplexing system (i.e., plots #1 and #3 for case \(m = 10\)).

3. Which system has the minimum average time and why?