1. Consider a transmission link with fixed link capacity $C = 1.5\ Mb/s$, an infinite buffer, and a Poisson packet arrival process with rate $\lambda = 1000\ p/s$. Assume that the packet length distribution is exponential with mean $L = 1000\ b/p$.

   (a) Compute the mean number of packets in the system (including in the transmitter). Compute the mean delay for a packet.

   (b) Now assume that the arrival rate of packets has risen to $\lambda = 2000\ p/s$, so we double the transmission capacity to $C = 3\ Mb/s$. What happens to the mean number of packets in the system? What happens to the mean delay for a packet? Justify your answer computationally and intuitively.

2. Consider a transmission link with a finite buffer modeled as an M/M/1/N queueing system, where N is the total number of buffer slots (including one in the server). Assume packet arrivals with rate $\lambda = 23\ p/s$ and fixed link capacity $C = 28,800\ b/s$. Approximate the packet length distribution by an exponential with mean $L = 1000\ b/p$. Compute the smallest buffer size, N, which would yield a blocking probability less than 10^{-4}.

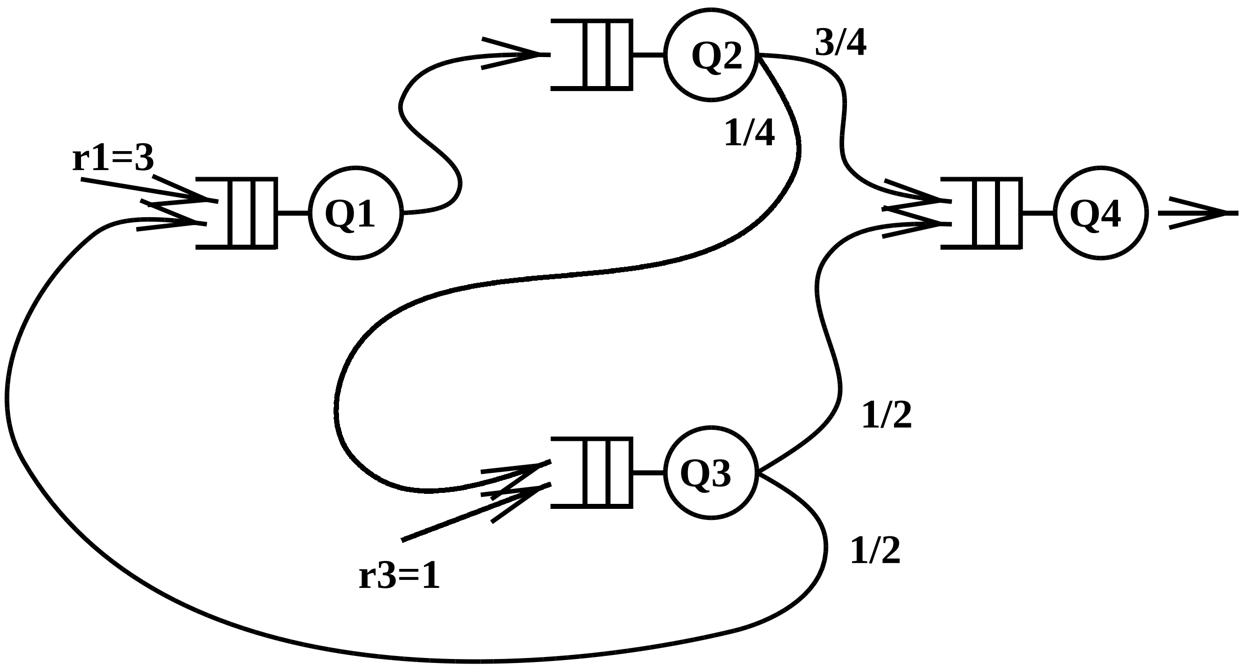
3. Consider a transmission link with fixed link capacity $C = 1.5\ Mb/s$, $\lambda = 750\ p/s$ and mean packet length $L = 1000\ b/p$. Using the Pollaczek-Khinchine (P-K) Formula compute the delay $E(T)$ for the following three cases

   (i) All packets have the same length ($\sigma^2 = 0$),

   (ii) The packet length distribution is exponential,

   (iii) The variance of service time is $\sigma^2 = 16 \times 10^{-6}$.

4. Consider the queueing network depicted below. All servers have a capacity of 5 packets/sec. The fractions on the links represent routing probabilities.



(a) Carefully write out the equations for $\lambda_1, \lambda_2, \lambda_3, \lambda_4$, the total arrival rates at Q1, Q2, Q3, Q4, respectively. Solve for $\lambda_1, \lambda_2, \lambda_3, \lambda_4$. Be sure to check your answer before proceeding further. Note that r1 and r3 are the external arrival rates at Q1 and Q3, respectively.

(b) Compute the mean delay $E(T_i)$ in each queue, Qi, i = 1, 2, 3, 4.

(c) Compute the mean delay for an arbitrary packet in this network.

(d) Compute the mean delay for a packet which travels Q3→Q1→Q2→Q4.

(e) Are your answers in parts (c) and (d) the same? Should they agree? Clearly explain why or why not.