1. **(Fair Rate Computation).** Suppose you have a 10 Mbps link that is used to provide Internet access to four customers that pay you 30 dollars/month each. You want to allocate bandwidth to the four active flows fairly. At the moment, suppose flows one to flow four request 5, 4, 2, and 1 Mbps, respectively. Compute the fair rates for each flow.

2. **(Weighted Fair Queuing using Round Robin Scheduling).** Three packets $p_1$, $p_2$, and $p_3$ belonging to three different flows 1, 2, and 3 arrive at the router at the time 0, 5, and 10 ms. The sizes of $p_1$, $p_2$, and $p_3$ are 10,000, 20,000, and 5,000 bits. The service rate of the output link is 1 Mbps.

   (a) Using the Round Robin scheduling scheme and assume the idealized fluid system model and equal weight for all the flows, draw the graph that depicts the number of bits in each queue as a function of time. Note the graph should have three curves, see slides 27 and 28 of the lecture notes.

   (b) Using the Round Robin scheduling scheme and assume the realistic system in which packets cannot be pre-empt and equal weight for all the flows, determine the service (sending) order of the packets $p_1$, $p_2$, and $p_3$ using the packet finishing times.

   (c) Redo part (a) with the assumption that the weights for flows are $w_1 = 2$, $w_2 = w_3 = 1$.

   (d) Redo part (b) with the assumption that the weights for flows are $w_1 = 2$, $w_2 = w_3 = 1$.

3. **(Token Bucket).** Given the parameters of a token bucket for a flow is $(b, r, R) = (1 \text{ Mbits}, 0.5 \text{ Mbps}, 1 \text{ Mbps})$.

   (a) Suppose there are initially 1 Mbits (or 1000000 tokens) in the bucket, and the incoming flow arrives at the router at the rate of 0.75 Mbps. Using the token bucket algorithm to regulate the flow, what is the output link rate at the time 1s and 10s?

   (b) Suppose there are initially 1 Mbits (or 1000000 tokens) in the bucket, and the incoming flow arrives at the router at the rate of 2 Mbps. How long before the number of tokens reaches zero for the first time?