1. Suppose a router receives the following packets in the order listed at about the same time. Assume all the packets are destined to the same output port, all relevant buffers are empty and large enough to keep all arriving packets. Further, the output port is currently busy.

<table>
<thead>
<tr>
<th>Packet</th>
<th>Size (bytes)</th>
<th>Flow</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>180</td>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>180</td>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>180</td>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>180</td>
<td>C</td>
<td>4</td>
</tr>
</tbody>
</table>

a) Give the order in which the packets above will leave the router assuming the router implements fair queuing. (Please use the packet numbers to indicate the order, e.g., 1, 2, 3, 4, 5, 6, 7 is one possible ordering.)

b) Now assume the router implements weighted fair queuing instead. In what order will the packets leave the router?
2. Consider the binary input sequence shown below. Show the input voltage signal, as well as how the bits would be modulated using each of amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK). The first bit has been drawn for you.

3. Consider a token bucket being used to shape traffic that has a replenishment rate \( r = 10 \) KBps, a maximum drain rate \( R = 100 \) KBps, and a bucket size \( b = 50 \) KB. Assume that the bucket starts off full. The shaper is applied to a sender that emits 25KB-packets every 0.5 seconds in a periodic manner, starting at \( t=0 \) seconds. Assume that the shaper does not start sending a packet until the full number of tokens necessary are present in the bucket.

   a) How many tokens are in the bucket at \( t=1.5 \) seconds?

   b) What is the first moment in time when the shaper will delay/queue a packet?

   c) For how long will that packet be delayed?
4. Consider the network shown below, in which horizontal lines represent Autonomous Systems (ASes), and numbered vertical lines are inter-provider links. A, B, C, D, and E are networks connected to a particular provider below (i.e., customers of the indicated AS). For the purposes of this problem, an AS path can be written as a comma separated path from one provider to another. I.e. the route from C to A through Provider P would be <Q, P, S> Take note that in an all-knowing sense there are actually two other loop-free routes from C to A, namely <Q, R, S> and <Q, S> but, depending on the business relationships between the providers, only certain routes will be advertised and/or selected.

a) Suppose that P, Q, R, and S are all peer autonomous systems; i.e. each connected pair of ASes has a peer-to-peer relationship. S has a peer relationship to P, Q, and R, but R only has peer relationships to Q and S because it has no direct link to P. Each AS applies the default BGP routing policy, and there are no Local Prefs in use.

i) What route would D use to send traffic to network C? If one does not exist, say why.

ii) What route would B use to send traffic to network D? If one does not exist, say why.
b) Now suppose ASes P, Q, R, and S adopt a route-selection policy that prefers routes that use the “closest” inter-provider link, minimizing their own cost (e.g., S would prefer to use link 1 over link 3 or 5 for any outbound traffic from network A because link 1 is closest to A, but it can only use link 1 if there is a known route to the destination that has P as the first AS in the route). Further, the relationships are different from part a) P, R, and S are all customers of Q. Additionally, P and S are peers, and S and R are peers.

i) What route would B use to send traffic to network A?

ii) What route would A use to send traffic to network B?

iii) What route would D use to send traffic to network E?

iv) What route would E use to send traffic to network C?

c) Finally, suppose the ASes adjust their BGP route selection policy, instead choosing the “furthest” link. Additionally, the autonomous system relationships have changed again. Now R is a customer of S and S is a customer of P, while Q has peer-to-peer relationships with each of P, R, and S.

i) What route would C use to send traffic to network B?

ii) What route would C use to send traffic to network D?

iii) What route would A use to send traffic to network C?

iv) What route would D use to send traffic to network A?