1. The virtual path/circuit table shown below is of the type introduced on page 1-13 of the lecture notes.

<table>
<thead>
<tr>
<th>base</th>
<th>size</th>
</tr>
</thead>
<tbody>
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<td>0</td>
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</tr>
<tr>
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<td>3</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
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<td>8</td>
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<tr>
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<td>3</td>
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<tr>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>output</th>
<th>VPI</th>
<th>VCI</th>
</tr>
</thead>
<tbody>
<tr>
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<td>4</td>
</tr>
<tr>
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<td>15</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>31</td>
</tr>
<tr>
<td>9</td>
<td>31</td>
<td>35</td>
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<tr>
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</tr>
<tr>
<td>11</td>
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<td>14</td>
<td>12</td>
<td>29</td>
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<tr>
<td>15</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>16</td>
<td>15</td>
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<td>21</td>
<td>14</td>
</tr>
<tr>
<td>19</td>
<td>12</td>
<td>35</td>
</tr>
</tbody>
</table>

When a cell with (VPI,VCI)=(3,5) arrives at the input port with this VPI/VCI table, what output is the cell sent to? What are the values of the (VPI,VCI) field of the forwarded copy?

Repeat for arriving cells with (VPI,VCI)= (2,2), (5,1) and (6,3).

2. How much time is needed to send a single cell on a link operating at 600 Mb/s? Suppose a cell enters the last position in a 256 cell buffer in the output port processor of an ATM switch? How much time will it take before the cell is transmitted on the link, assuming the link data rate is 150 Mb/s? How long does it take a cell to travel over a 1000 mile link? How many cells can be simultaneously traveling over a 1000 mile link operating at 150 Mb/s? How do all the above answers change when the link data rate is 2.4 Gb/s?

3. How many pixels per second must be sent across a virtual circuit carrying a video signal with a resolution of 640 by 480 pixels per frame and a frame rate of 30 frames
per second? What data rate is needed to support this at 24 bits per pixel? If JPEG is used to encode this at a rate of 20 Mb/s, approximately how many bits per pixel is that on average? How do the answers change if the video signal has a resolution of 320 by 240 pixels and a frame rate of 15 frames per second? What about 1280 by 960 pixels and 60 frames per second? What instruction processing rate do you estimate a workstation would need to handle a single video stream in software for each of these options if there is no encoding of the video. What about if the workstation software must do JPEG encoding?

4. This problem concerns the amount of routing memory required for single stage switches supporting multicast. For simplicity, assume that the switch supports virtual circuits only and that the virtual path identifier is ignored on the input side and set to zero on the output.

Consider a single-stage switch with 16 ports and using a bus to interconnect the ports. Each input has a virtual circuit table that for point-to-point virtual circuits specifies the output port and output VCI a cell with a given input VCI is to be sent to; for multicast virtual circuits, it instead specifies Multicast Identifier. The MI is used at the output ports for another table lookup that yields the outgoing VCI. Assume that we want to support a total of 4096 entries on each input link and each output link and we want to allow up to 500 VCIs on each output to be associated with multicast virtual circuits. How many entries must each of the input tables have and how many bits per entry?

How many entries must each of the output tables have and how many bits per entry, assuming that the output tables are implemented using direct lookup?

How many entries must each of the output tables have and how many bits per entry, assuming that the output tables are implemented using CAMs?

5. Consider the bus-based ATM switch shown below. In the input table, when the multicast bit is 0, the connection is point-to-point. When the multicast bit is 1, the connection is multicast. In the output table, if the multicast bit is 1, the cell with the given MI is copied to that output port.

Based on the contents of the virtual circuit tables, make a list of all the connections that are currently configured. For each point-to-point connection, give the input (port,VCI) pair and output (port,VCI) pair. For each one-to-many connection, give the input (port,VCI) pair and the set of output (port,VCI) pairs. For each many-to-many connection, give the set of input (port,VCI) pairs and the set of output (port,VCI) pairs. Assume that for each input (port,VCI) that is configured, there is a 20 Mb/s data stream entering the switch. What is the load carried on each of the output ports?
6. The TranSwitch CUBIT chip can support a CellBus clock rate of 33 MHz. At this clock rate, what is the maximum number of OC-3C ports that can operated at the full link speed simultaneously? Be sure to account for the CellBus's internal overhead properly. Consider a switch with 32 OC-3C ports and carrying point-to-point virtual circuits with bursty traffic having a peak rate of 20 Mb/s and an average rate of 2 Mb/s. Assuming that each input port and each output port carries the same number of these virtual circuits, what is the total number of such virtual circuits that the switch can carry while keeping the probability of overloading the CellBus below .001.

7. Consider a queue with a capacity of $B$ cells. When implementing the control for such a queue, one must determine how to handle cells that arrive when the queue is full. The simplest thing to do in such cases is to always discard cells that arrive when the queue is full. However, it is possible to avoid discarding such cells when the first cell in the queue is leaving, since the bytes of the arriving cell can be written into the memory locations vacated by the departing cell. Which of these two options is implemented by the queue represented by the queueing model on page 2-10 of the notes? Show how you would modify the model to implement the other option.

8. Write a program to implement the burst-arrival queueing model described on page 2-17 of the lecture notes. Use your program to generate a plot of cell loss (as a function of offered load) for a queue with room for 1000 cells. Include three curves: one for an average burst size of 10 cells, one for an average burst size of 1000 cells and one for an average burst size of 100 cells. Vary the offered load from 0.2 to 2 and plot the cell loss on a logarithmic scale going from $10^{-6}$ to 1 (similar to the plot on
page 2-18). Compare your results to the simulation results shown on page 2-26. Comment on the similarities and differences.