1. 

```
xor r7, r8, r9 ; instruction 1
add r9, r1, r8 ; instruction 2
sub r4, r9, r1 ; instruction 3
add r3, r9, r2 ; instruction 4
and r7, r2, r3 ; instruction 5
or r8, r7, r4 ; instruction 6
```

(a) flow dependence from instruction 1 to instruction 6 through r7
flow dependence from instruction 2 to instruction 3 through r9
flow dependence from instruction 2 to instruction 4 through r9
flow dependence from instruction 3 to instruction 6 through r4
flow dependence from instruction 4 to instruction 5 through r3
flow dependence from instruction 5 to instruction 6 through r7

(b) In cycle 16, the pipeline stages will contain the following instructions:

```
<table>
<thead>
<tr>
<th>IF</th>
<th>ID</th>
<th>EX</th>
<th>MEM</th>
<th>WB</th>
</tr>
</thead>
<tbody>
<tr>
<td>inst 6</td>
<td>inst 5</td>
<td>inst 4</td>
<td>inst 3</td>
<td>inst 2</td>
</tr>
</tbody>
</table>
```

The destination register of instruction 2 will be written => r9 will be written.
The source registers of instruction 5 will be read => r2 and r3 will be read.

2. page size of 64K bytes => 16-bit page offset => 34 – 16 = 18-bit virtual page number:

```
34
```

```
  virtual page number  page offset
```

```
18 16
```

=> number of page table entries is $2^{18}$
each entry is 24 bits = 3 bytes

=> total size of the page table = $(2^{18})(3 \text{ bytes}) = 768 \text{ Kbytes}$
3. hits and misses are as follows:

1-miss, 17-miss, 13-miss, 1-hit, 6-miss, 22-miss, 21-miss, 5-miss, 14-miss, 6-hit, 5-hit, 1-hit, 21-hit, 17-miss, 1-hit, 5-hit, 6-hit, 22-hit

The final cache contents are as follows: (it is OK to organize the slots horizontally within each set)

<table>
<thead>
<tr>
<th>set</th>
<th>address</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>17 5</td>
</tr>
<tr>
<td></td>
<td>13 17</td>
</tr>
<tr>
<td></td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
4. (a) For P1 on C1:

\[
CPI = \frac{(2 \times 10^9 \text{ cycles/sec})(6 \text{ sec})}{4 \times 10^9 \text{ instructions}} = 3
\]

For P1 on C2:

\[
CPI = \frac{(5 \times 10^9 \text{ cycles/sec})(4 \text{ sec})}{5 \times 10^9 \text{ instructions}} = 4
\]

(b) For P2 on C1:

\[
\text{instructions executed} = \frac{(2 \times 10^9 \text{ cycles/sec})(12 \text{ sec})}{3 \text{ cycles/instruction}} = 8 \times 10^9
\]

For P2 on C2:

\[
\text{instructions executed} = \frac{(5 \times 10^9 \text{ cycles/sec})(16 \text{ sec})}{4 \text{ cycles/instruction}} = 20 \times 10^9 = 2 \times 10^{10} \quad \text{(either is OK)}
\]