1. (10%) Consider a MIPS processor with a five-stage pipeline and internal forwarding mechanism as described below:
   Stage 1: IF Instruction fetch
   Stage 2: ID Instruction decode and register read
   Stage 3: EXE Execution or address calculation
   Stage 4: MEM Data memory access
   Stage 5: WB Write back

   How many clock cycles does it need for the following code? Please also identify all the hazards with a figure.
   ```
   lw $2, 20($1)
   and $4, $2, $5
   or $8, $2, $6
   add $9, $4, $2
   slt $1, $5, $7
   ```

2. (20%) Please explain the following terms:
   a. Parallel processing program (5%)
   b. Process-level parallelism (5%)
   c. Instruction-level parallelism (5%)
   d. Cache coherency (5%)

3. (10%) In computer memory hierarchy, a memory reference can encounter three different types of misses; a TLB miss, a page fault, and a cache miss. Please answer Yes or No to each of (a), (b), (c), (d) and (e). (5% + 2%)

<table>
<thead>
<tr>
<th>Possible?</th>
<th>TLB</th>
<th>Page Table</th>
<th>Cache</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>Hit</td>
<td>Miss</td>
<td>Hit</td>
</tr>
<tr>
<td>(b)</td>
<td>Hit</td>
<td>Hit</td>
<td>Miss</td>
</tr>
<tr>
<td>(c)</td>
<td>Hit</td>
<td>Miss</td>
<td>Miss</td>
</tr>
<tr>
<td>(d)</td>
<td>Miss</td>
<td>Hit</td>
<td>Miss</td>
</tr>
<tr>
<td>(e)</td>
<td>Miss</td>
<td>Miss</td>
<td>Hit</td>
</tr>
</tbody>
</table>

4. (10%) Please answer True or False to each of the following statements. (Each question is worth 2%)
   a. More powerful instructions mean higher performance.
   b. Computers at low utilization imply low power consumption.
   c. To benefit from a multiprocessor, an application must be concurrent.
   d. GPUs rely on graphics DRAM chips to reduce memory latency and thereby increase performance on graphics applications.
   e. There is no way to reduce compulsory misses.
[資料結構]

5. (12%) With very brief reasons, state whether the following statements are true or false.
   a) The best case running time of insertion-sort is O(n). (3%)
   b) The best case running time of heap-sort is O(n). (3%)
   c) Merge-sort is stable. (3%)
   d) The worst case complexity of quick-sort is O(n log n). (3%)

6. (8%) Answer the following questions.
   a) Order the five growth rates in decreasing order: 100n, n log n, 100000, n!, 2n log n. (4%)
   b) Show, using the definition of the big-Oh, that the function f(n) = 0.01n^2 + 100 is O(n^2). (4%)

7. (15%) A tree is represented as
   A(B(CD)E(F(G)H(IJK)L(MNO))))
   a) Please show its tree structure. (5%)
   b) Convert it to the corresponding binary tree. (5%)
   c) Give the preorder representation the binary tree in b). (5%)

8. (15%) Consider the following linked list:
   typedef struct listNode *listPointer;
   typedef struct listNode {
     int number;
     listPointer link;
   };
   a) Write a function that accepts a linked list and prints out all elements of it. (7%)
   b) Write a function that accepts a linked list and inverts it. (8%)