國立臺灣科技大學 112 學年度碩士班招生試題

系所組別：資訊工程系碩士班

科　　目：資訊工程概論

(總分為 100 分；所有試題務必於答案卷內頁依序作答，否則不予計分)

1. (15%) A is a two dimensional array, where the element A(3,2) is located at address 1110, and A(2,3) is located at 1115. Assume that each element is identified by one unique address, and A is declared as A(*m*,*n*). Is this array stored in row-major order or in column-major order? What is the value of *m*? What is the location of A(5,4)?

2. (10%) Consider the function **func** as shown below, where the two lists list1 and list2 are both ordered in ascending order.

```
struct item
{
   int value;
   struct item *next;
};

int func(struct item *list1, struct item *list2)
{
   struct item *ptr1, *ptr2;
   int count = 0;
   ptr1 = list1;
   ptr2 = list2;
   while ((ptr1 != NULL)&&(ptr2 != NULL))
   {
      if (ptr1->value < ptr2->value)
         ptr1 = ptr1 ->next;
      else if (ptr1->value > ptr2->value)
         ptr2 = ptr2->next;
      else
      {
         ptr1 = ptr1->next;
         ptr2 = ptr2->next;
         count++;
      }
   }
   return count;
}
```

If *m* and *n* are the number of items in list1 and list2 respectively, what is the worst-case time complexity of func(list1, list2)?

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3. (5%) The form of the master method, which is used to calculate the recurrence relations, is:

$$T(n) = aT\left(\frac{n}{b}\right) + f(n),$$

where n denotes the size of a problem, $a \geq 1$ and $b \geq 1$ are constants, and $f(\cdot)$ is a non-negative function of n. According to the formulation, we have three cases:

- If $f(n) = O(n^{\log_b a - \epsilon})$, for some constant $\epsilon > 0$, then $T(n) = \Theta(n^{\log_b a})$
- If $f(n) = \Theta(n^{\log_b a})$, then $T(n) = \Theta(n^{\log_b a} \log_2 n)$
- If $f(n) = \Omega(n^{\log_b a + \epsilon})$ for some constant $\epsilon > 0$, $af(\frac{n}{b}) \leq cf(n)$ for some constant $c < 1$ and all sufficiently large n, then $T(n) = \Theta(f(n))$

For a given problem, its runtime can be expressed as:

$$T(n) = 3T\left(\frac{1}{4}n\right) + n\log_2 n$$

Please use the master method to outline its time complexity. All the calculation steps should be written down.

4. (5%) Alice tries to insert a set of keys $[17, 88, 62, 30, 28, 77, 90, 45, 51]$ sequentially into a fresh hash table with size 3 based on the linear probing strategy $g(x, i) = (h(x) + i) \bmod M$, where M is the size of the hash table and $h(x) = x \bmod M$. If the overflow condition happens, rehash will be performed by doubling the table size and computing the new hash value for the elements from the beginning in the old table. Following that, the new table continues to be filled with uninserted elements. Please write down the final result of the hash table.

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5. (15%) One day, Bob creates three novel sorting algorithms to sort N integer elements stored in an array ARR. The index begins from 0 for the array, and the pseudo codes are listed below:

Method 1:

```
method_one (ARR , N)
{
    int TEMP, k, i
    for k=1 to N-1
        TEMP = ARR[k]
        i = k-1
        while TEMP <= ARR[i] && i >= 0
            ARR[i+1] = ARR[i]
            i = i-1
        ARR[i+1] = TEMP
}
```

Method 2:

```
method_two (ARR , N)
{
    int TEMP_a, TEMP_b, k, j
    for k=0 to N-1
        TEMP_a = ARR[k]
        TEMP_b = k
        for j=k+1 to N-1
            if TEMP_a >= ARR[j]
                TEMP_a = ARR[j]
                TEMP_b = j
        TEMP_a = ARR[k]
        ARR[k] = ARR[TEMP_b]
        ARR[TEMP_b] = TEMP_a
}
```

Method 3:

```
method_three (ARR , N)
{
    int TEMP, k, j
    for k=0 to N-1
        for j=0 to N-k
            if ARR[j] >= ARR[j+1]
                TEMP = ARR[j]
                ARR[j] = ARR[j+1]
                ARR[j+1] = TEMP
}
```

(1) (5%) Which statement(s) is(are) true about the first method?

(A) It does not work for sorting.

(B) The best case time complexity is $O(n)$

(C) The average case time complexity is $O(n^2)$

(D) It is a stable sorting algorithm

(E) None of the above statements is true

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(2) (5%) Which statement(s) is(are) true about the second method?
- (A) The best case time complexity is $O(n^2)$
- (B) The average case time complexity is $O(n^2)$
- (C) The worst case time complexity is $O(n^2)$
- (D) It is a stable sorting algorithm
- (E) None of the above statements is true

(3) (5%) Which statement(s) is(are) true about the third method?
- (A) It does not work for sorting.
- (B) The best case time complexity is $O(n^2)$
- (C) The average case time complexity is $O(n)$
- (D) It is a stable sorting algorithm
- (E) None of the above statements is true

6. (17%) IEEE 754 is a well-known standard for representing floating-point numbers. To pack more bits, hidden leading 1 bit is used implicitly for normalized numbers.
(1) (4%) The single precision representation takes 32 bits, where the first bit is a sign bit, the following 8 bits represent the exponent with a bias of 127, and the last 23 bits represent the fraction. Please encode -100/3 by using single precision IEEE 754 representation and then convert the binary encoding into a hexadecimal number.

(2) (4%) The "half-precision" representation (denoted as FP16) is only 16 bits wide. The leftmost bit is still the sign bit, the exponent is 5 bits wide with a bias of 15, and the fraction is 10 bits long. Please encode -100/3 by using the FP16 representation and then convert the binary encoding into a hexadecimal number.

(3) (4%) The "bfloat16" representation also uses 16 bits. The leftmost bit is still the sign bit, the exponent is 8 bits wide with a bias of 127, and the fraction is 7 bits. Please encode -100/3 by using the bfloat16 representation and then convert the binary encoding into a hexadecimal number. (4%)

(4) (5%) Which of the aforementioned representations is the best for modern machine-learning applications? You are required to justify your answer.

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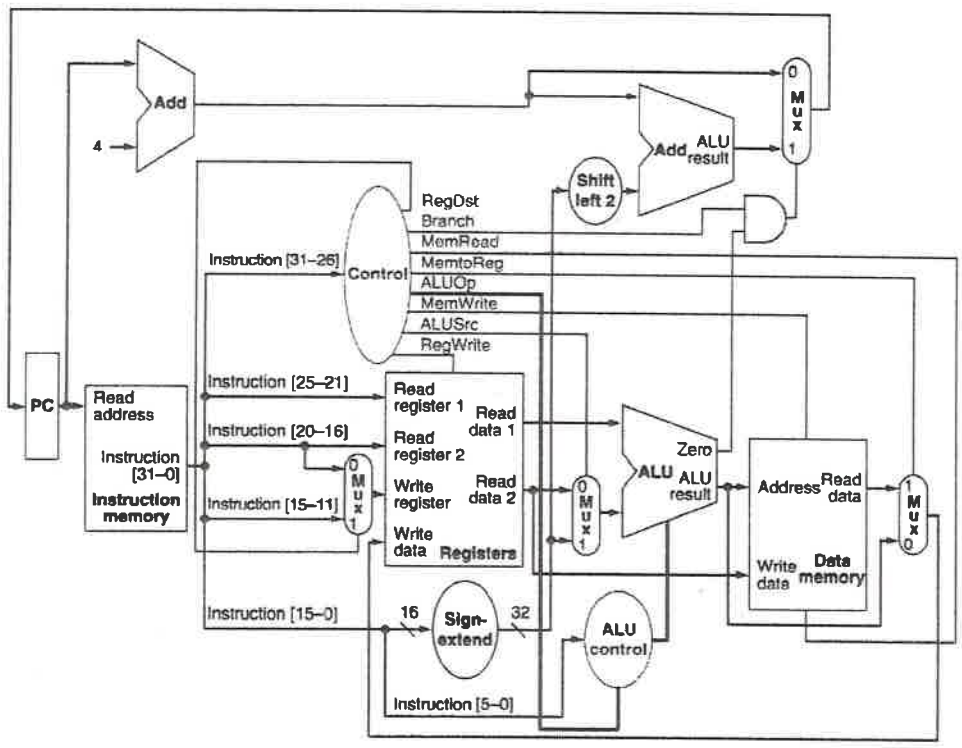
7. (8%) Given the MIPS register convention and the schematic of a single-cycle design below.

(1) (4%) Please add the necessary data path and control signal if you want to implement "jalr" (jump-and-link register) instruction.

(2) (4%) Please add the necessary data path and control signal if you want to create a new instruction "ret" (return), which updates both the program counter and stack pointer simultaneously.



Name	Register number	Usage
$zero	0	The constant value 0
$v0–$v1	2–3	Values for results and expression evaluation
$a0–$a3	4–7	Arguments
$t0–$t7	8–15	Temporaries
$s0–$s7	16–23	Saved
$t8–$t9	24–25	More temporaries
$gp	28	Global pointer
$sp	29	Stack pointer
$fp	30	Frame pointer
$ra	31	Return address

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8. (10%) Consider a paging system using 16-bit addresses and 4096-byte pages. The page tables of two processes are shown below.

Process 1

Page	Page frame
0	5
1	0
2	2
3	7

Process 2

Page	Page frame
0	4
1	1
2	6
3	3

Please convert the following logical addresses to the corresponding physical addresses. All numbers are given in decimal.

(1) (5%) Process 1: 13256

(2) (5%) Process 2: 11234

9. (8%) Consider the following page reference sequence:

3, 2, 7, 1, 2, 1, 3, 4, 6, 7, 7, 6, 0, 5, 4, 5, 6, 3, 0 , 1.

Assuming demand paging with three frames, how many page faults would occur if LRU replacement algorithm is used? Assume that all frames are initially empty.

10. (7%) Consider the following snapshot of a system with four resource types R1, R2, R3, and R4, and four processes A, B, C, and D:

	Allocation				Request				Available			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
A	1	0	1	1	1	2	0	0	0	0	0	0
B	1	0	1	0	0	0	0	0				
C	1	1	0	0	1	0	0	1				
D	0	1	0	0	1	0	1	0				

Is the system in a deadlock state? If the system is in a deadlock state, list all processes that involve in a deadlock.