國立中山大學112學年度
碩士班暨碩士在職專班招生考試試題

科目名稱：作業系統與資料結構【資工系碩士班甲組】

－作答注意事項－

考試時間：100分鐘

- **考試開始鈴響前不得翻閱試題，並不得書寫、劃記、作答。**請先檢查答案卷（卡）之應考證號碼、桌角號碼、應試科目是否正確，如有不同立即請監試人員處理。
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國立中山大學112學年度碩士班暨碩士在職專班招生考試試題

科目名稱：作業系統與資料結構【資工系碩士班甲組】　　題號：434003

※本科目依簡章規定「不可以」使用計算機(問答申論題)　　

INSTRUCTIONS: If any question is unclear or you believe some assumptions need to be made, state your assumptions clearly at the beginning of your answer.

1. What are printed by each of the following C program?

(a) (5%)

```
int a=40, b=24;
printf("%d \n",(a&(~b))|((~a)& b));
   // ~: bitwise NOT; &: bitwise AND; |: bitwise OR
```

(b) (10%)

```
int b[ ]={ 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42};
int h(int i) {
   if (i==1)  {
      printf("%d  ", b[i]);
      return (b[1]);
   }
   else  if (i % 2 == 0) {
      printf("%d   ", b[i]);
      b[i/2] += i/2;
      return (h(i/2));
   }
   else {
      b[i+1] ++;
      return (h(i+1));
   }
}
int main( )
{
   h(9);
}
```

2. The pseudo code for the insertion sort is given as follows.

```
Read input elements into a[ ]; //stored in a[1], a[2], ..., a[n]
for i = 2 to n do
{
   j = i;
   while (j >= 2) and  (a[j] < a[j-1]) do
   {
      Swap(a[j], a[j-1]); // exchange a[j] and a[j-1]
      j = j-1;
   }
}
```

(a) (5%) Suppose that the input elements are 3, 9, 6, 5, 8, 2. How many times (counts) are needed for the execution of `Swap( )`?

(b) (5%) Suppose that the input is a permutation of {1,2,3,..., n}. What permutation will make `Swap( )` be executed the least times? How many times?

(c) (5%) Suppose that the input is a permutation of {1,2,3,..., n}. What permutation will make `Swap( )` be executed the most times? How many times?

國立中山大學112學年度碩士班暨碩士在職專班招生考試試題

科目名稱：作業系統與資料結構【資工系碩士班甲組】　　題號：434003

※本科目依簡章規定「不可以」使用計算機(問答申論題)　　

3. (10%) Suppose that there are 6 data elements A, B, C, D, E, F with their searching frequencies 4, 9, 1, 6, 8, 7, respectively, where $A < B < C < D < E < F$. Please present the optimal binary search tree built with these 6 elements such that the searching cost is minimized.

4. (10%) The stamp cost problem (SCP) is to stick the exact cost of stamps on an envelope. In the post office, there are five types of stamps:1, 2, 3, 4, 5 dollars. You are asked to calculate all possible combination ways for getting j dollars. Let $g(i,j)$ denote the number of combination ways for j dollars, where only stamps with 1, 2, ...,i dollars are used. Note that i and j are both positive integers, $1 \le i \le 5$ and $1 \le j \le n$ (an integer constant). For example, $g(2, 3)=2$, since there are two ways for constituting 3 dollars with 1-dollar and 2-dollar stamps: 1+1+1 and 1+2. As another example, $g(3, 4)=4$, since four ways can be used to get 4 dollars with 1-dollar, 2-dollar and 3-dollar stamps: 1+1+1+1, 1+1+2, 2+2 and 1+3. However, the stamps with 3-dollar and 4-dollar have been sold out (no such stamps) today. Other stamps are assumed to be unlimited. Please give the recursive formula to calculate $g(i,j)$. You can assume that $g(i,0)=1$, $g(i,j)=0$ for $1 \le i \le 5$ and $j \le -1$.

5. (a) (7%) What are the seven common components in a process control block?

   (b) (3%) What are the purposes of mutex, semaphore, and condition variable?

6. (a) (6%) What is the difference of the binding of instructions and data to memory addresses in compile time, load time, and execution time?

   (b) (4%) How to solve the thrashing problem by using the working-set model?

7. (a) (6%) Explain sequential, direct, and index accesses for a file.

   (b) (4%) What are consistency semantics for a file system?

8. (a) (4%) Explain how the deadlock prevention scheme works.

   (b) (3%) Explain three latencies concerned by a real-time system.

   (c) (3%) Give three reasons not to use caching in a distributed file system.

9. (10%) Explain the following terms:

   (a) vectored I/O

   (b) safety-critical system

   (c) logic bomb

   (d) turnaround time

   (e) race condition

國立中山大學112學年度
碩士班暨碩士在職專班招生考試試題

科目名稱：離散數學【資工系碩士班甲組】

－作答注意事項－

考試時間：100分鐘

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國立中山大學112學年度碩士班暨碩士在職專班招生考試試題

科目名稱：離散數學【資工系碩士班甲組】　　題號：434004

※本科目依簡章規定「不可以」使用計算機(問答申論題)　　

There are 8 problems in this test. Note that you should write down ***detailed steps*** *for the solution to each problem; otherwise, no credits for that problem will be given.*

1. [10%] What is the coefficient of $ab^6c^8d^5$ in the expansion of $(3a - b + 5c + 3d - 8)^{25}$?

2. [10%] Prove that for any $n \in Z^+$, $12n+17$ and $8n+11$ are co-prime.

3. [10%] There are 25 warehouses in a company for storing the products and the space of each warehouse is different. Assume that no two warehouses have the same size. How many warehouses at least can be used to consist of a sequence of consecutive logistics collection points, where a previous collection point need to have a larger space than the next one?

4. [10%] Let $\Sigma = \{t, v, w, x, y, z\}$ and $A = \bigcup_{n=1}^{11} \Sigma^n$. How many strings in A have xyz as a proper prefix?

5. [10%] Find a formula for the convolution of the following sequences,
   $a_n = (-1)^n, b_n = (-1)^n, c_n = 1^n$, for all $n \in \mathbf{N}$.

6. A ship carries 60 flags, 15 each of the colors red, white, blue, and black. Fifteen of these flags are placed on a vertical pole in order to communicate a signal to other ships.
   (a) [10%] How many of these signals use an odd number of black flags and an even number of red flags?
   (b) [10%] How many of the signals have at least five white flags or no blue flags at all?

7. (a) [10%] Find and solve a recurrence relation for the number of ways to park motorcycles and cars in a row of n spaces if each cycle requires one space and each car needs three.
   (b) [10%] Find and solve a recurrence relation for the number of ways to park motorcycles and cars in a row of n spaces if each cycle requires one space, each car needs three, and the cars come in four different colors.

8. [10%] For $a, b, n \in \boldsymbol{Z}^+$ and $n > 1$, prove that $a \equiv b \ (mod\ n) \Rightarrow\ gcd(a, n) = gcd(b, n)$.

國立中山大學112學年度
碩士班暨碩士在職專班招生考試試題

科目名稱：計算機結構【資工系碩士班甲組、乙組】

—作答注意事項—

考試時間：100分鐘

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國立中山大學112學年度碩士班暨碩士在職專班招生考試試題

科目名稱：計算機結構【資工系碩士班甲組、乙組】　　題號：434001

※本科目依簡章規定「不可以」使用計算機(問答申論題)

1. (20% total) Performance Calculations

1.1 (5%) The miss latency is 10 cycles. If the direct-mapped cache has a two-cycle hit latency, what is the average memory latency with a 15% miss rate?

1.2 (5%) The miss latency is 10 cycles. If the set-associative cache has a three-cycle hit latency, what the miss rate must the set-associative cache obtain to have a lower average latency than the direct-mapped cache with 15% miss rate?

1.3 (5%) Consider a workload with 30% branches and a 66.66% branch prediction accuracy (33.33% misprediction rate). You may ignore memory operations. For a simple five-stage pipeline, what is the CPI of this workload assuming a three-cycle misprediction penalty and a single-cycle latency for all other instructions?

1.4 (5%) Consider a workload with 30% branches and a 66.66% branch prediction accuracy (33.33% misprediction rate). You may ignore memory operations. Calculate under what condition a much deeper pipeline with double the core clock frequency will outperform the shallower pipeline?

2. (15% total) A memory system has four channels, and each channel has two ranks of DRAM chips. Each memory channel is controlled by a separate memory controller. Each rank of DRAM contains eight banks. A bank contains 32K rows. Each row in one bank is 8KB. The minimum retention time among all DRAM rows in the system is 64 ms. In order to ensure that no data is lost, every DRAM row is refreshed once per 64 ms. Every DRAM row refresh is initiated by a command from the memory controller which occupies the command bus on the associated memory channel for 5 ns and the associated bank for 40 ns. Let us consider a 1.024 second span of time. We define utilization (of a resource such as a bus or a memory bank) as the fraction of total time for which a resource is occupied by a refresh command. (Note: For each calculation in this question, you may leave your answer in simplified form in terms of powers of 2 and powers of 10.)

2.1 (5%) How many refreshes are performed by the memory controllers during the 1.024 second period in total across all four memory channels?

2.2 (5%) What command bus utilization, across all memory channels, is directly caused by DRAM refreshes?

2.3 (5%) What bank utilization (on average across all banks) is directly caused by DRAM refreshes?

3. (15% total) A benchmark searches for an entry in a linked list build from the following structure, which contains a key, a pointer to the next node in the linked list, and a pointer to the data entry.

```
struct node {
    int key;
    struct node *next;
    struct data  *ptr;
}
```

The following RISC-V code shows the core of the benchmark, which traverses the linked list and finds an entry with a particular key.

```
loop: LW   x3, 0 (x1)        # load a key
      LW   x4, 4 (x1)        # load the next pointer key
      SEQ  x3, x3, x2        # set x3 if x3 == x2
      BNEZ x3, end           # find the entry
      ADD  x1, x0, x4
      BNEZ x4, loop          # check the next code
end:
```

We run this benchmark on a single-issue in-order processor. The processor can fetch and issue (dispatch) one instruction per cycle. If an instruction cannot be issued due to a data dependency, the processor stalls. Integer instructions take one cycle to execute and the result can be used in the next

cycle. For example, if SEQ is executed in cycle 1, BNEZ can be executed in cycle 2. We also assume that the processor has a perfect branch predictor with no penalty for both taken and not-taken branches.

3.1 (5%) Assume that the system does not have a cache. Each memory operation directly accesses main memory and takes 50 CPU cycles. The load/store unit is fully pipelined, and non-blocking. After the processor issues a memory operation, it can continue executing instructions until it reaches an instruction that is dependent on an outstanding memory operation. How many cycles does it take to execute one iteration of the loop in steady state?

3.2 (5%) Now we add zero-overhead multithreading to the pipeline. A processor executes multiple threads, each of which performs an independent search. Hardware mechanisms schedule a thread to execute each cycle. In the first implementation, the processor switches to a different thread every cycle using fixed round robin scheduling. Each of the N threads executes one instruction every N cycle. What is the minimum number of threads that we need to fully utilize the processor, i.e., execute one instruction per cycle?

3.3 (5%) We change the processor to only switch to a different thread when an instruction cannot execute due to data dependency (data-dependent switching). What is the minimum number of threads to fully utilize the processor now? Note that the processor issues instructions in order in each thread.
Hint: consider how many instructions each thread can execute in steady state.

4. (15% total) For a given compute kernel, we define a tensor's reuse interval (RI) as the number of different elements of that tensor that have been referenced between each re-reference of the same element. For example, consider the following:

```
for m in [0, M)
  for n in [0, N)
    Z[m, n] = A[m] * B[n]
```

Since A's element is used at every iteration of the inner loop, its RI is 1. Each element of B is re-referenced after N references, so its RI is N. Z has "infinite" reuse interval (i.e., no data reuse) since no element is re-referenced throughout the computation:

RI of A = 1
RI of B = N
RI of Z = infinite / no reuse

4.1 (5%) Consider the following Matrix-Matrix multiply pseudocode, which multiplies two dense matrices A and B to produce Z:

```
;; Multiply two matrices A and B to produce Z
;; First matrix A is M×K
;; Second matrix B is K×N
;; Thus, resulting matrix Z is M×N
for m in [0, M)
  for n in [0, N)
    for k in [0, K)
      Z[m, n] += A[m, k] * B[k, n]
```

What are the reuse intervals for the three matrices? Provide your answers in terms of M, N, and K.

4.2 (5%) Now consider the following where we re-order the loop nest:

```
for k in [0, K)
  for m in [0, M)
    for n in [0, N)
      Z[m, n] += A[m, k] * B[k, n]
```

What are the reuse intervals for the three matrices? Provide your answers in terms of M, N, and K.

4.3 (5%) Now consider the following scenario:

- M = 500, N = 1000, and K = 30
- A, B, and Z are dense matrices.
- The matrices are resident in DRAM at the beginning of the computation kernel.

Your wish to design a matrix-matrix multiply accelerator given the above assumptions. Your goal is to maximize compute intensity, defined as the average number of computations you perform per DRAM access. You are given the following hardware budget:

- A multiply-accumulate (MAC) unit with a flip-flop on each input and the output.
- An SRAM array large enough to store 32 elements.

Which order of loop nest in Questions 4.1 or 4.2, would you choose, and given the order how would you partition the SRAM budget among the different elements to maximize compute intensity? You can reorder the loop nests from Questions 4.1 and 4.2, but do not add more loops (e.g., no tiling).

5. (15% total) Considering a system which applies the Sequential Consistency (SC). Suppose that three processes, P1, P2 and P3 are applied with different processors on a system (the values of RA, RB, RC were all zeros before the execution):

P1	P2	P3
P1.1: ST (A), 1	P2.1: ST (B), 1	P3.1: ST (C), 1
P1.2: LD RC, (C)	P2.2: LD RA, (A)	P3.2: LD RB, (B)

After all processes are executed, it is possible for the system to have multiple machine states. For example, {RA, RB, RC} = {1,1,1} is possible if the execution sequence of instructions is P1.1→P2.1→P3.1→P1.2→P2.2→P3.2. Also, {RA, RB, RC}= {1,1,0} is possible if the sequence is P1.1 → P1.2 → P2.1 → P3.1 → P2.2 → P3.2. For each state of {RA, RB, RC}: {0,0,0} {0,1,0} {1,0,0} {0,0,1}, specify the execution sequence of instructions that results in the corresponding state. If the state is NOT possible with SC, just put X.

6. (20% total) Assuming that you want to design a more efficient, machine-specific implementation of an algorithm by observing an existing cache system. The patterns that access various bytes in the system can be used to determine the cache characteristics. However, the only statistic that you can collect on this system is cache hit rate after performing the access patterns as listed below:

Sequence No.	Addresses Accessed (Oldest to Youngest)	Hit Rate
1	0 4 8 16 64 128	1/2
2	31 8192 63 16384 4096 8192 64 16384	5/8
3	32768 0 129 1024 3072 8192	1/3

Assume that the cache is initially empty at the beginning of the first sequence, but not at the beginning of the second and third sequences. The sequences are executed back-to-back, i.e., no other accesses take place between the three sequences. Thus, at the beginning of the second (third) sequence, the contents are the same as at the end of the first (second) sequence. Based on what you observe, what are the following characteristics of the cache? Explain to get points!

6.1 (5%) Cache block size (8, 16, 32, 64, or 128 B)?
6.2 (5%) Cache associativity (1-, 2-, 4-, or 8-way)?
6.3 (5%) Cache size (4 or 8 KB)?
6.4 (5%) Cache replacement policy (LRU or FIFO)?

國立中山大學112學年度
碩士班暨碩士在職專班招生考試試題

科目名稱：工程數學【資工系碩士班乙組】

—作答注意事項—

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國立中山大學112學年度碩士班暨碩士在職專班招生考試試題

科目名稱：工程數學【資工系碩士班乙組】　　題號：434002

※本科目依簡章規定「不可以」使用計算機(問答申論題)　　

1. (16%) The matrix A is shown below.

$$A=\begin{bmatrix} 1 & 2 & 3 & 4 & 5 \\ -1 & 6 & 7 & 8 & 9 \\ 0 & 0 & 1 & 11 & 12 \\ 0 & 0 & 0 & 3 & 14 \\ 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

1.1 (8%) Show A is invertible.

1.2 (8%) Find $\det(A^{-1})$.

2. (16%) Let A and $\boldsymbol{b}$ denote the matrix

$$A=\begin{bmatrix} 2 & 1 \\ -2 & 0 \\ 2 & 3 \end{bmatrix} \quad \boldsymbol{b}=\begin{bmatrix} -5 \\ 8 \\ 1 \end{bmatrix}$$

2.1 (10%) Find a least square solution to $\boldsymbol{Ax}=\boldsymbol{b}$ i.e., a vector $\hat{\boldsymbol{x}} \in \mathbb{R}^2$ minimizing $\|A\hat{\boldsymbol{x}}-\boldsymbol{b}\|$.

2.2 (6%) Using answer in 2.1, or otherwise, find the orthogonal projection $\hat{\boldsymbol{b}}$ of $\boldsymbol{b}$ onto the column space of A, i.e., $\hat{\boldsymbol{b}}=\mathbf{Proj}_{\mathbf{Col}(A)}(\boldsymbol{b})$.

3. (16%) Consider the initial value problem,

$$4y''+4y'+y=0, \quad y(0)=1, \quad y'(0)=2$$

3.1 (8%) Solve the initial value problem.

3.2 (8%) Change the second initial condition to $\boldsymbol{y'(0)=b>0}$ and find the solution as a function of $\boldsymbol{b}$.

4 (20%) Find the general solution of the following differential equation.

$$y''+2y'=3+4sin(2t)$$

5 (16%) Find the inverse Laplace transform of the following function.

$$f(t)=(t-3)u_2(t)-(t-2)u_3(t)$$

6. (16%) Write $f(x)$ as a Fourier series over $-1 \le x \le 1$ where

$$f(x)=\begin{cases} 1+2x, & if \ -1 \le x < 0, \\ 1-2x, & if \ \ 0 \le x \le 1 \end{cases}$$

國立中山大學112學年度
碩士班暨碩士在職專班招生考試試題

科目名稱：離散數學與演算法【資工系資安碩班碩士班】

－作答注意事項－

考試時間：100分鐘

- **考試開始鈴響前不得翻閱試題，並不得書寫、劃記、作答。**請先檢查答案卷（卡）之應考證號碼、桌角號碼、應試科目是否正確，如有不同立即請監試人員處理。
- **答案卷限用藍、黑色筆(含鉛筆)書寫、繪圖或標示**，可攜帶橡皮擦、無色透明無文字墊板、尺規、修正液（帶）、手錶(未附計算器者)。每人每節限使用一份答案卷，請衡酌作答(不得另攜帶紙張，亦不得使用應考證空白處作為計算紙使用)。
- 答案卡請以2B鉛筆劃記，不可使用修正液（帶）塗改，未使用2B鉛筆、劃記太輕或污損致光學閱讀機無法辨識答案者，後果由考生自負。
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國立中山大學112學年度碩士班暨碩士在職專班招生考試試題

科目名稱：離散數學與演算法【資工系資安碩班碩士班】　　題號：485001

※本科目依簡章規定「不可以」使用計算機(問答申論題)　　

There are 9 problems in this test. Note that you should write down detailed steps for the solution to each problem; otherwise, no credits for that problem will be given.

1. Two n-digital integers (leading zeros allowed) are considered equivalent if one is a rearrangement of the other. (E.g., 305697, 079563, and 567930 are considered equivalent six-digital integers.)
   (a) [10%] How many six digital integers are not equivalent?
   (b) [10%] If the digitals 3, 5, and 7 can appear at most once, how many nonequivalent six-digital integers are there?

2. [10%] Find the exponential generating function for the sequence 0!, 1!, 2!, 3!, ….

3. [10%] There are 65 boxes in an office and the size of each box is different. Assume that no two boxes have the same size. How many boxes at least can be used together to pack a stuff that is smaller than the smallest box (a box of larger size can contain a smaller one)?

4. [10%] How many positive integers n divide $69373n + 342247$?

5. [10%] Find the generating function for the number of partitions of the nonnegative integer n into summands, where each summand must appear an odd number of times.

6. [10%] Prove that the number of primes is infinite.

7. (Algorithm points) [10%] Please describe the algorithm of Tower of Hanoi using recursion and analyze its time complexity in detail.

8. (Algorithm points) [10%] Please describe the algorithm of Merge Sort and analyze its time complexity in detail.

9. (Algorithm points) [10%] Please describe the Dijkstra algorithm and analyze its time complexity in detail.

國立中山大學112學年度
碩士班暨碩士在職專班招生考試試題

科目名稱：作業系統【資工系資安碩班碩士班】

－作答注意事項－

考試時間：100分鐘

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國立中山大學112學年度碩士班暨碩士在職專班招生考試試題

科目名稱：作業系統【資工系資安碩班碩士班】　　題號：485002

※本科目依簡章規定「不可以」使用計算機(問答申論題)　　

INSTRUCTIONS: If any question is unclear or you believe some assumptions need to be made, state your assumptions clearly at the beginning of your answer.

1. [Operating System: 80%]

(1)Please answer the following questions regarding process protection in an operating system. (20%)

(a) Please show and explain the principle of least privilege.

(b) Please explain what is the domain of protection?

(2)Given the following set of processes all of which arrive the system at time 0, with the length of the CPU burst given in milliseconds, please answer the following questions and show the order of processes for each question. (15%)

Process	Burst Time	Priority
P_1	8	3
P_2	2	2
P_3	4	1
P_4	2	4
P_5	8	5
P_6	6	6

(a) What are the completion time and average waiting time of these processes by using the first-come, first-served scheduling algorithm?

(b) What are the completion time and average waiting time of these processes by using the shortest-job-first scheduling algorithm?

(c) Suppose a smaller priority number stands for a higher priority. What is the completion time of these processes by using a non-preemptive priority scheduling algorithm?

(3)Please show and explain the main characteristics of Hadoop Distributed File System (HDFS) and Yet Another Resource Negotiator (YARN). (20%)

(4)Please show and explain how the instructions and data are bound to memory addresses during the periods of load, compile, and run. (10%)

(5)What are the breach of confidentiality, breach of integrity, breach of availability, theft of service, and denial of service? (15%)

2. [Security: 20%]

(1) Explain what is Advanced Persistent Threat (APT)? (5%)

(2) Explain what is Convert Channel/Side Channel Attack? (3%)

(3) What are the required cryptographic algorithms to achieve confidentiality, integrity, and non-repudiation, simultaneously, to protect a message and how? (5%)

(4) Please describe what is a mobile malware? (3%)

(5) What kinds of security protocols can provide end-to-end security in application layer? Please take at least one specific protocol as an example and explain why. (4%)