國立中山大學109學年度
碩士暨碩士專班招生考試試題

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

- **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109學年度碩士暨碩士專班招生考試試題

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. (10% total) Assume a 32-bit, byte-addressed machine with virtual addressing. The two high-order bits are **11** is treated as **unmapped**. These addresses are only accessible by the operating system and bypass virtual address translation. The answers need to express as a multiple of a power of 2, or in terms of KB, MB, GB, or TB as appropriate.

1.1 (2%) What is the maximum amount of **physical memory** this system can address?

1.2 (2%) What is the maximum amount of **virtual memory** any single process on this system can address?

1.3 (2%) How many **virtual pages** are available to each process, assuming 4KB pages?

1.4 (2%) Assume each page table entry is 4 bytes, how much memory would a single-level page table require?

1.5 (2%) Assuming a two-level page table where half the bits of the virtual page number are used to index the first level, and the other half are used to index the second level, how many second-level page tables can a process use if its total page table size is limited to 400KB?

2. (15% total) The instruction latency for a given CPU is shown in Table 1.

Table 1.

Instructions	Breakdown	Latency
load	5%	3 cycles
add	10%	5 cycles
divide	10%	8 cycles
branch	50%	2 cycles
shift left	15%	5 cycles
shift right	10%	1 cycles

2.1 (3%) Calculate the **CPI** of the given CPU?

2.2 (4%) **Variant 1:** All **add** instructions are replaced with corresponding **subtract** instructions that take the same amount of time. Calculate the **CPI** of the **Variant 1**?

2.3 (4%) **Variant 2:** Remove the highest-latency instruction, and replace all those instructions with additional latency of three cycles for the lowest latency instruction in the mix. Calculate the **CPI** of the **Variant 2** (relative to the original instruction count)?

2.4 (4%) **Variant 3:** Reduce the latency for **divides** by a factor of four, but increase the latencies of **branches** by 50%. Calculate the **CPI** of the **Variant 3**?

3. (10% total) A old program needs to be parallelized. Then, it can run faster on modern multicore processors. In order to execute the program with parallel and serial portions more efficiently, a custom heterogeneous processor needs to be designed.
   - The processor has one large core which executes code more quickly but takes greater die area on-chip, the multiple small cores which execute code more slowly but consume less area, all sharing one processor die.
   - When program in its parallel portion, all of its threads execute only on small cores.
   - When program in its serial portion, the one active thread executes on the large core.
   - Performance (execution speed) of a core is proportional to the square root of its area.
   - Assume 16 units of die area available. A small core takes 1 unit of die area. The large core can take any number of units of die area n^2, where n is the positive number. Area not used by the large core will be filled with smaller cores.
   - The **serial portion** is only **10%** of total work, and the **parallel portion** is the remaining **90%**.

3.1 (5%) What would be the speed up for the fastest possible execution of the program?

3.2 (5%) What would the same program's speedup be if all 16 units of die area were used to build a homogeneous system with 16 small cores, the serial portion ran on one of the small cores, and the parallel portion ran on all 16 small cores?

4. (15% total) An 8-bit byte-addressable virtual address space and the physical memory has 128 bytes. Each page contains 16 bytes. A simple, one level translation scheme is used and the page table resides in physical memory. The initial contents of the frames of the physical memory are shown in Table 2.

Table 2.

Frame Number	Frame Contents
0	Empty
1	Page 13
2	Page 5
3	Page 2
4	Empty
5	Page 0
6	Empty
7	Page Table

A three-entry translation lookaside buffer (TLB) that uses Least Recently-Used (LRU) replacement is added to this system. Initially, this TLB contains the entries for pages 0, 2, and 13. (Note: LRU is used to select pages for replacement in physical memory.)
References (to pages): 0, 13, 5, 2, 14, 14, 13, 6, 6, 13, 15, 14, 15, 13, 4, 3.

4.1 (4%) What is the hit rate of the TLB for this sequence of references?
4.2 (3%) At the end of this sequence, what three entries are contained in the TLB?
4.3 (8%) What are the contents of the 8 physical frames?

5. (15% total) Assume a machine with a 7-stage pipeline. Assume that branches are resolved in the sixth stage. Assume that 20% of instructions are branches. Answer the following questions.

5.1 (5%) How many instructions of wasted work are there per branch misprediction on this machine?
5.2 (5%) Assume N instructions are on the correct path of a program and assume a branch predictor accuracy of A. Write the equation for the number of instructions that are fetched on this machine in terms of N and A.
5.3 (5%) If the machine were modified so that it used the dual path execution (where an equal number of instructions are fetched from each of the two branch paths). Assume that branches are resolved before new branches are fetched. Write how many instructions would be fetched in this case as a function of N.

6. (10% total) A byte-addressable system with 16-bit address ships with a three-way set associative, write-back cache. The cache implements a true LRU replacement policy using the minimum number of replacement policy bits necessary to implement it. The tag store requires a total of 264 bits of storage. What is the block size of the cache?

7. (10% total) A byte-addressable processor is connected to a single memory channel that has a single rank of DRAM. The physical address space is 32 bits, and the processor uses the following mapping shown in Table 3, to index the DRAM. Each DRAM row has a certain number of columns, where a column has the same size of a cache line. The processor uses 64-byte cache lines. The Columns is 6 bits and the Cache Line Offset is also 6 bits. In addition, the row size is 4 KB.

Table 3 Mapping from the physical address to DRAM

MSB			LSB
Rows	Banks	Columns	Cache Line Offset

Table 4 shows the memory request queue that has 4 pending memory request at time 0.
Assuming that

- A row buffer hit takes **50 cycles**
- A row buffer conflict takes **250 cycles**.
- Requests going to different banks can be processed by the banks in parallel.
- All the row buffers are closed at times 0.
- The controller cannot issue two requests at the same time. Each request takes **10 cycles** to process, so it takes **10 cycles** between issuing two separate requests to the memory.
- The controller employs First Ready-First Come First Serve (FR-FCFS) scheduling policy.

Table 4. the state of the memory request queue at time 0.

Request	Physical Address
A (oldest)	0x0000-4000
B	0x0000-1040
C	0x0000-3040
D (youngest)	0x0000-4a00

If it takes **320 cycles** to finish processing all four requests in the memory, **at least** how many banks does this rank of DRAM have?

8. (15% total) Please answer the following questions.

8.1 (4%) Give two disadvantages of static code scheduling.

8.2 (4%) Give two disadvantages of dynamic code scheduling.

8.3 (4%) What are two mechanisms that dynamic code scheduling uses to mitigate the shortcomings of static code scheduling, and why does each mechanism help?

8.4 (3%) What types of dependencies can occur during out-of-order execution?

國立中山大學109學年度
碩士暨碩士專班招生考試試題

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—

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國立中山大學109學年度碩士暨碩士專班招生考試試題

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. (10%) Consider the following set of processes, with the length of the CPU-burst time given in milliseconds:

Process	Burst Time	Priority
P_1	10	3
P_2	1	1
P_3	2	4
P_4	1	5
P_5	5	2

The processes are assumed to have arrived in the order P_1, P_2, P_3, P_4, P_5, all at time 0.

   (a) (5%) What is the completion time of process P_1 using a nonpreemptive priority (a smaller priority number implies a higher priority) scheduling?

   (b) (5%) What is the average waiting time using shortest-job-first scheduling?

2. (10%) A machine has 64-bit virtual addresses and 32-bit physical addresses. Pages are 32 KB. How many entries are needed for the page table?

3. (10%) Consider the two-dimensional array a:

```
double a[][] = new double[250][250];
```

   where each double occupies 8 bytes and `a[0][0]` is at location 200, in a paged system with pages of size 200 bytes. A small process is in page 0 (locations 0 to 199) for manipulating the matrix; thus, every instruction fetch will be from page 0. For three page frames, how many page faults are generated by the following array initialization loops, using LRU replacement and assuming (1) page frame 0 has the process in it, (2) the other two are initially empty, and (3) the array is stored in memory column-major.

   (a) (5%)

```
for (int i = 0; i < 250; i++)
    for (int j = 0; j < 250; j++)
        a[i][j] = 0;
```

   (b) (5%)

```
for (int j = 0; j < 250; j++)
    for (int i = 0; i < 250; i++)
        a[i][j] = 0;
```

4. (10%) What would be the output of the following C program that uses the Pthreads API? (*Note that the line numbers are for reference only.*)

```
1  #include <stdio.h>
2  #include <stdlib.h>
3  #include <unistd.h>
4  #include <pthread.h>
5  #include <sys/types.h>
6  #include <sys/wait.h>
7
8  static void *runner(void *param)
9  {
10     (* (int*) param)--;
11     pthread_exit(0);
12 }
```

```
13
14 int main(int argc, char **argv)
15 {
16     int value = 11;
17     pid_t pid = fork();
18     if (pid > 0) {
19         int status;
20         waitpid(-1, &status, 0);
21         printf("A=%d\n", value--);
22     }
23     else if (pid == 0) {
24         pid_t pid = fork();
25         if (pid > 0) {
26             int status;
27             waitpid(-1, &status, 0);
28             printf("B=%d\n", --value);
29         }
30         else if (pid == 0) {
31             pid_t pid = fork();
32             pthread_t tid;
33             pthread_create(&tid, NULL, runner, &value);
34             pthread_join(tid, NULL);
35             if (pid > 0) {
36                 int status;
37                 waitpid(-1, &status, 0);
38                 printf("C=%d\n", value++);
39             }
40             else {
41                 printf("D=%d\n", ++value);
42             }
43         }
44         else {
45             return 1;
46         }
47     }
48     else {
49         return 1;
50     }
51     return 0;
52 }
```

5. (10%) Given a UNIX *i*-node with ten direct blocks and three levels of indirect blocks (i.e., a single, a double, and a triple) and assuming that the sizes of a pointer and a block are, respectively, 8 bytes and 4 Kbytes, answer the following questions.

   (a) (5%) What would be the size of the smallest file allowed in bytes?

   (b) (5%) What would be the size of the largest file allowed in bytes?

6. (20%) Suppose that a disk drive has 1024 cylinders, numbered from 0 to 1023. The drive is currently serving a request at cylinder 200, and the previous request was at cylinder 125. The queue of pending requests, in FIFO order, is

   50, 500, 250, 800, 350, 550, 400, 600, 100.

   Starting from the current head position, what is the *total distance* (in cylinders) that the disk arm moves to satisfy all the pending requests for each of the following disk scheduling algorithms?

   (a) (4%) SSTF

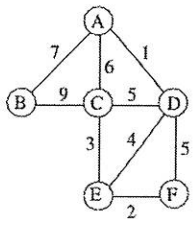
   (b) (4%) SCAN

   (c) (4%) LOOK

(d) (4%) C-SCAN

(e) (4%) C-LOOK

7. (5%) Given the following weighted graph, show the order in which the edges are added to the minimum cost spanning tree using Kruskal's algorithm. ***(Use weight to represent edges in your answer and just show the order.)***



8. (5%) Show the Huffman tree created from the following nodes arranged in a priority queue.

A	B	C	D	E	F	G	H	I	J
6	9	12	14	18	24	27	29	35	45

9. (10%) For any input of size n and assuming that k_1 denotes the maximum number of digits and k_2 the number of buckets, what is the average-case running time of each of the following sorting algorithms: (a) selection sort, (b) merge sort, (c) heap sort, (d) radix sort, and (e) bucket sort?

10. (10%) The Ackermann function $A(m,n)$ is defined recursively for non-negative integers m and n as follows:

$$A(m,n) = \begin{cases} n+1 & \text{if } m = 0, \\ A(m-1,1) & \text{if } m > 0 \text{ and } n = 0, \\ A(m-1, A(m,n-1)) & \text{if } m > 0 \text{ and } n > 0. \end{cases}$$

Its value grows very quickly, even for small values of m and n. For instance, $A(4,1) = 65533$. What would be the values of $A(3,2)$ and $A(2,4)$?

國立中山大學109學年度
碩士暨碩士專班招生考試試題

科目名稱：離散數學【資工系碩士班甲組】

—作答注意事項—

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國立中山大學109學年度碩士暨碩士專班招生考試試題

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 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. In how many ways can we distributed 10 identical green balls into 5 distinct containers so that
   (a) [6%] no container is left empty?
   (b) [6%] the third container has an even number of balls in it?

2. [10%] If $a, b \in \boldsymbol{Z}^+$, and both are odd, prove that $2|(a^2 + b^2)$ but $4\nmid (a^2 + b^2)$.

3. Let $|A| = 7$.
   (a) [6%] How many closed binary operations functions $f: A \times A \longrightarrow A$ are there?
   (b) [6%] How many of these closed binary operations are commutative?

4. [10%] An auditorium has a seating capacity of 900. How many seats must be occupied to guarantee that at least two people seated in the auditorium have the same first and last initials?

5. [10%] In how many ways can 3600 identical envelopes be divided, in package of 25, among five student groups so that each group get at least 150, but not more than 1000, of the envelopes?

6. Find the generating function for the number of partitions of the nonnegative integer n into summands where
   (a) [6%] each summand must appear an even number of times;
   (b) [6%] each summand must be even.

7. [10%] If $a_n, n \geq 0$, is the unique solution of the recurrence relation $a_{n+1} - da_n = 0$, and $a_3 = 156/77$, $a_5 = 1628/6336$, what is d?

8. (a) [6%] How many vertices and how many edges are there in the complete bipartite graphs $K_{m,n}$, where $m, n \in \boldsymbol{Z}^+$.
   (b) [6%] If the graph $K_{m,12}$ has 72 edges, what is m?

9. [12%] 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109學年度
碩士暨碩士專班招生考試試題

科目名稱：工程數學【資工系碩士班乙組】

—作答注意事項—

考試時間：100分鐘

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國立中山大學109學年度碩士暨碩士專班招生考試試題

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(選擇題)　　

※All the following questions are True/False questions. Please select "A" for "True" and "B" for "False."

I. (10%) Discrete Fourier Transform (DFT) is a widely used transformation method in signal processing. According to DFT matrix, please determine the correctness of the following descriptions.

1. (2%) All circulant matrices are made diagonal by the Discrete Fourier Transform (DFT), regardless of the generating vector x.
2. (2%) DFT matrix is not a kind of symmetric matrix.
3. (2%) DFT matrix is an unitary matrix.
4. (2%) The DFT is a linear transform.
5. (2%) The orthogonality is not the property of the DFT matrix.

II. (10%) The four eigenvalue of a 4×4 matrix A are 1, 1, 2, and 3. Please determine the correctness of the following descriptions.

6. (2%) The determinant of A is 6.
7. (2%) The trace of A is 7.
8. (2%) The rank(A-I)=3, where I is the 4x4 identity matrix.
9. (2%) The determinant of the adjoint matrix A^+ is 6.
10. (2%) The matrix A is a simple matrix.

III. (10%) If matrix A and matrix B are row equivalent. Please determine the correctness of the following descriptions.

11. (2%) The row space of A is equal to the row space of B.
12. (2%) The column space of A is equal to the column space of B.
13. (2%) The null space of A is equal to the null space of B.
14. (2%) The rank(A) is equal to the rank(B).
15. (2%) The determinant of A is equal to the determinant of B.

IV. (20%) Please read the following True/False questions and determine the correctness of each description.

16. (2%) If A and B are invertible 2×2 matrices, then $(AB)^{-1}=A^{-1}B^{-1}$.
17. (2%) If A is a 3×3 matrix such that the system $Ax = 0$ has only the trivial solution, then the equation $Ax = b$ is consistent for every b in $\mathbb{R}^3$.
18. (2%) If P and D are $n \times n$ matrices, then $\det(PDP^{-1}) = \det(D)$.
19. (2%) If $T\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x \\ 0 \end{bmatrix}$, then $\text{Null(T)} = span\left\{\begin{bmatrix} 1 \\ 0 \end{bmatrix}\right\}$.
20. (2%) If A and B are any 2×2 matrices, then $AB = BA$.
21. (2%) The matrix $A = \begin{bmatrix} 1 & 0 & 1 \\ 1 & 2 & 1 \\ 0 & 3 & 0 \end{bmatrix}$ is not invertible.
22. (2%) The matrix of the linear transformation T which reflects points about the x-axis and then about the y-axis is the same as the matrix of the linear transformation S which rotates points about the origin by 180 degrees counterclockwise.
23. (2%) If V is a set that contains the 0-vector, and such that whenever u and v are in V, then $u + v$ is in V, then V is a vector space.
24. (2%) If A and B are square matrices, then $(A + B)^{-1} = A^{-1} + B^{-1}$.
25. (2%) If A and B are square matrices, then $\det(A + B) = \det(A) + \det(B)$.

V. **(50%) Let f: $\mathbb{R}\to\mathbb{R}$ be the 20-periodic function such that**

$$f(t)=\begin{cases}-1, \text{ if } -10<t\le -3\\ t^{50}, \text{ if } 3<t\le 10\end{cases}$$

and let

$$f(t)\approx\frac{a_0}{2}+\sum_{n=1}^{\infty}\left(a_n\cos\frac{\pi nt}{10}+b_n\sin\frac{\pi nt}{10}\right)$$

be the general Fourier Series of f. Please determine the correctness of the following descriptions.

26. (10%) For every $t\in(-20,55)$, the following series can be converged.

$$\frac{a_0}{2}+\sum_{n=1}^{\infty}\left(a_n\cos\frac{\pi nt}{10}+b_n\sin\frac{\pi nt}{10}\right)$$

27. (10%) For every integer $n\ge 1$, we have

$$b_n=\frac{1}{10}\int_{77}^{97}f(t)\sin\frac{\pi nt}{10}dt$$

28. (10%) For every integer $n\ge 1$, we have

$$b_n=\frac{2}{10}\int_{0}^{10}f(t)\sin\frac{\pi nt}{10}dt$$

29. (10%) For every $t\in(-2,3)$, we have

$$0=\sum_{n=1}^{\infty}\frac{\pi n}{10}\left(-a_n\sin\frac{\pi nt}{10}+b_n\cos\frac{\pi nt}{10}\right)$$

30. (10%) We have

$$-1=\frac{a_0}{2}+\sum_{n=1}^{\infty}\left(a_n\cos\frac{42\pi n}{10}+b_n\cos\frac{42\pi n}{10}\right)$$

國立中山大學109學年度
碩士暨碩士專班招生考試試題

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

- **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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- **試題及答案卷（卡）請務必繳回，未繳回者該科成績以零分計算。**
- **試題採雙面列印，考生應注意試題頁數確實作答。**
- **違規者依本校招生考試試場規則及違規處理辦法處理。**

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. (10%) Consider the following set of processes, with the length of the CPU-burst time given in milliseconds:

Process	Burst Time	Priority
P_1	10	3
P_2	1	1
P_3	2	4
P_4	1	5
P_5	5	2

The processes are assumed to have arrived in the order P_1, P_2, P_3, P_4, P_5, all at time 0.

   (a) (5%) What is the completion time of process P_1 using a nonpreemptive priority (a smaller priority number implies a higher priority) scheduling?

   (b) (5%) What is the average waiting time using shortest-job-first scheduling?

2. (10%) A machine has 64-bit virtual addresses and 32-bit physical addresses. Pages are 32 KB. How many entries are needed for the page table?

3. (10%) Consider the two-dimensional array a:

```
double a[][] = new double[250][250];
```

   where each double occupies 8 bytes and a[0][0] is at location 200, in a paged system with pages of size 200 bytes. A small process is in page 0 (locations 0 to 199) for manipulating the matrix; thus, every instruction fetch will be from page 0. For three page frames, how many page faults are generated by the following array initialization loops, using LRU replacement and assuming (1) page frame 0 has the process in it, (2) the other two are initially empty, and (3) the array is stored in memory column-major.

   (a) (5%)

```
for (int i = 0; i < 250; i++)
    for (int j = 0; j < 250; j++)
        a[i][j] = 0;
```

   (b) (5%)

```
for (int j = 0; j < 250; j++)
    for (int i = 0; i < 250; i++)
        a[i][j] = 0;
```

4. (10%) What would be the output of the following C program that uses the Pthreads API? (*Note that the line numbers are for reference only.*)

```
1  #include <stdio.h>
2  #include <stdlib.h>
3  #include <unistd.h>
4  #include <pthread.h>
5  #include <sys/types.h>
6  #include <sys/wait.h>
7
8  static void *runner(void *param)
9  {
10     (* (int*) param)--;
11     pthread_exit(0);
12 }
```

```
13
14 int main(int argc, char **argv)
15 {
16     int value = 11;
17     pid_t pid = fork();
18     if (pid > 0) {
19         int status;
20         waitpid(-1, &status, 0);
21         printf("A=%d\n", value--);
22     }
23     else if (pid == 0) {
24         pid_t pid = fork();
25         if (pid > 0) {
26             int status;
27             waitpid(-1, &status, 0);
28             printf("B=%d\n", --value);
29         }
30         else if (pid == 0) {
31             pid_t pid = fork();
32             pthread_t tid;
33             pthread_create(&tid, NULL, runner, &value);
34             pthread_join(tid, NULL);
35             if (pid > 0) {
36                 int status;
37                 waitpid(-1, &status, 0);
38                 printf("C=%d\n", value++);
39             }
40             else {
41                 printf("D=%d\n", ++value);
42             }
43         }
44         else {
45             return 1;
46         }
47     }
48     else {
49         return 1;
50     }
51     return 0;
52 }
```

5. (10%) Given a UNIX *i*-node with ten direct blocks and three levels of indirect blocks (i.e., a single, a double, and a triple) and assuming that the sizes of a pointer and a block are, respectively, 8 bytes and 4 Kbytes, answer the following questions.

   (a) (5%) What would be the size of the smallest file allowed in bytes?

   (b) (5%) What would be the size of the largest file allowed in bytes?

6. (20%) Suppose that a disk drive has 1024 cylinders, numbered from 0 to 1023. The drive is currently serving a request at cylinder 200, and the previous request was at cylinder 125. The queue of pending requests, in FIFO order, is

   50, 500, 250, 800, 350, 550, 400, 600, 100.

   Starting from the current head position, what is the *total distance* (in cylinders) that the disk arm moves to satisfy all the pending requests for each of the following disk scheduling algorithms?

   (a) (4%) SSTF

   (b) (4%) SCAN

   (c) (4%) LOOK

(d) (4%) C-SCAN

(e) (4%) C-LOOK

7. (10%) What are the necessary conditions for a deadlock to occur in a system?

8. [Security: 20%]
   (a) (6%) Explain what "Confidentiality", "Integrity", and "Availability" means.
   (b) (4%) Explain what "Botnet" and "Malware" means.
   (c) (5%) Please explain what is "Digital Envelope" and how it works.
   (d) (5%) Explain the main techniques used to construct "Bitcoin" and its main network, and what is "Proof-of-Work".

國立中山大學109學年度
碩士暨碩士專班招生考試試題

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

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國立中山大學109學年度碩士暨碩士專班招生考試試題

科目名稱：離散數學與演算法【資工系資安碩班碩士班】　　題號：485002

※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. Determine the number of integer solutions of $x_1 + x_2 + x_3 + x_4 = 64$, where
   (a) [7%] $x_i \geq 1, 1 \leq i \leq 4$.
   (b) [7%] $x_1, x_2, x_1 > 2, 0 < x_4 \leq 14$.

2. [12%] If p, q are primes, prove that $p|q$ if and only if $p = q$.

3. [12%] How many positive integers n divide $99373n + 342246$?

4. [12%] Let $f, g: \mathbf{R} \to \mathbf{R}$, where $g(x) = 1 - x + x^2$ and $f = ax + b$. If $(g \circ f)(x) = 9x^2 - 9x + 3$, determine a, b.

5. [12%] Find the exponential generating function for the sequence 0!, 1!, 2!, 3!, ….

6. [12%] If $a_0 = 0, a_1 = 2, a_2 = 6$, and $a_3 = 56$ satisfy the recurrence relation $a_{n+2} + ba_{n+1} + ca_n = 0$, where $n \geq 0$ and b, c are constants, determine b, c and solve for a_n.

7. (a) [7%] Please state the quick sort algorithm in detail.
   (b) [7%] Please derive the time complexity of quick sort by the method of recurrence relation for the input data size n.

8. [12%] Let $T = (V, E)$ be a complete m-ary tree of height h. This tree is called a *full* m-ary tree if all of its leaves are at level h. If T is a full m-ary tree with height 7 and 279,936 leaves, how many internal vertices are there in T?