國立雲林技術學院
八十六學年度研究所碩士班入學考試試題

所別：電機工程技術研究所
電子與資訊工程技術研究所
科目：電子學

1. Figure 1 shows a circuit for a digital-to-analog converter (DAC). The circuit accepts a 4 bits input binary word $a_3a_2a_1a_0$ where $a_0, a_1, a_2,$ and a_3 take the values of 0 and 1, and it provides an analog output v_o proportional to the value of the digital input. Each of the bits of the input word controls the correspondingly numbered switch. For instance, if a_2 is 0 then switch s_2 connects the 20 $k\Omega$ register to ground, while if a_2 is 1 then s_2 connects the 20 $k\Omega$ register to the $+5V$ power supply. Show that v_o is given by

$v_o = -\frac{R_f}{16}[2^0a_0 + 2^1a_1 + 2^2a_2 + 2^3a_3]$. (25 %)

2. Figure 2 shows a transconductance amplifier with an infinite input resistance, a 10 $k\Omega$ output resistance, and a transconductance $G_m = 0.1\frac{A}{V}$. A 1 $M\Omega$ resistor R_f is connected from the output of the amplifier back to its input. The amplifier is fed with a source v_s having a source resistance R_s. Find R_{in}, v_o/v_i, and R_{out}. (25 %)

3. Provide a design for a voltmeter circuit similar to the one in Figure 3, which is intended to function at frequencies of 20 Hz and above. It should be calibrated for sine-wave input signals to provide an output of $+10V$ for an input of $1V$ rms. The input resistance should be as high as possible. To extend the bandwidth of operation, keep the gain in the ac part of the circuit reasonably small. The design should be such as to reduce the size of the capacitor C required. The largest value of resistor available is 1 $M\Omega$. (25 %)

4. A logic inverter having the circuit of Figure 4 with $V^+ = 5V$ and $R_L = 1\ k\Omega$, and the switch having an on-resistance of 100 Ω, is switched at a 10 MHz rate. The load capacitance is 10 pF, and the input remains high an average of 75 % of the time. Calculate the static, dynamic, and total power dissipation in the gate. What is the power dissipated in the switch? (25 %)

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科目：電子學

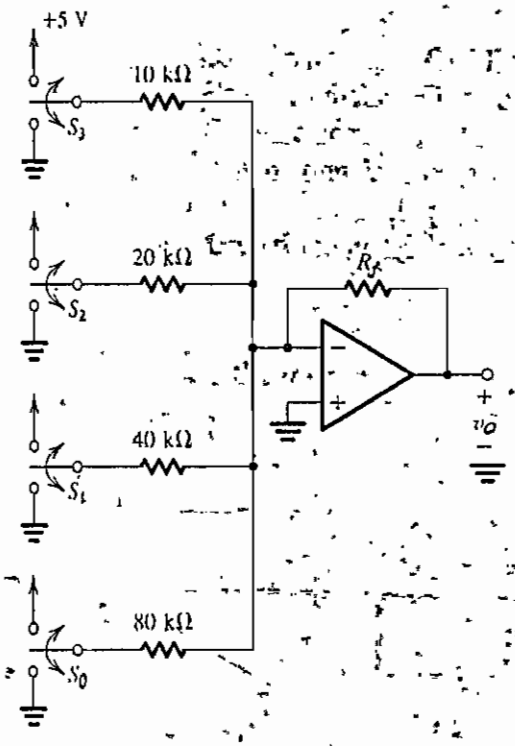

Fig. 1

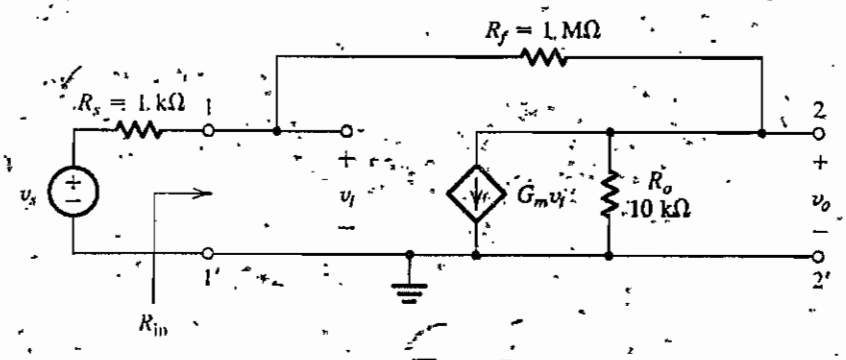

Fig. 2

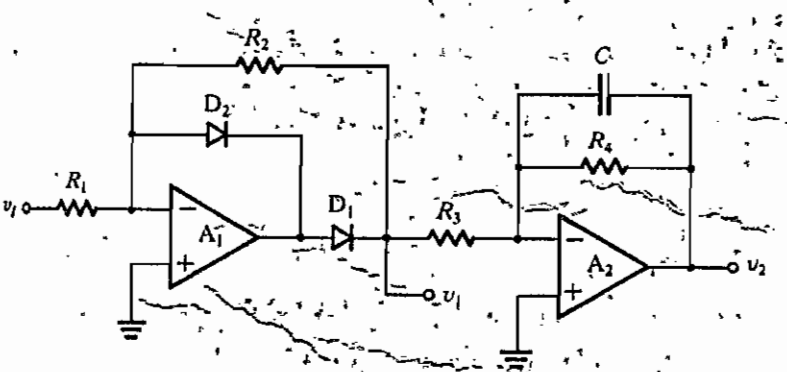

Fig. 3

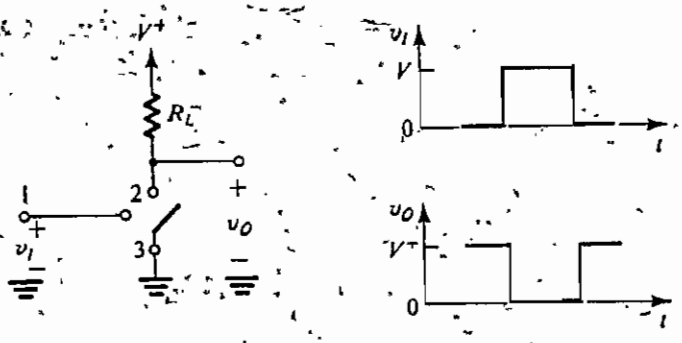

Fig. 4

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科目：工程數學

1.Find the general solution of the following equation

a) $y'' + 2y' + y = 3e^{-x} + x$ (10%)

b) $y'' + 5y' = e^{-x}\sin 3x$ (6%)

c) $y'' + 4y = \sec x$, for $-\frac{\pi}{4} < x < \frac{\pi}{4}$ (12%)

2.Solve the initial value problem

a) $y' + y = x + \sin x; y(0) = 1$ (10%)

b) $y'' - 8ty' + 16y = 3; y'(0) = 0 = y(0)$ (12%)

3. (a) Show that $\begin{bmatrix} a & x \\ 0 & b \end{bmatrix}$ is invertible if and only if $a \neq 0$ and $b \neq 0$.

(b) If A and B are square and invertible matrices, show that

$$\begin{bmatrix} a & x \\ 0 & b \end{bmatrix}^{-1} = \begin{bmatrix} A^{-1} & -A^{-1}XB^{-1} \\ 0 & B^{-1} \end{bmatrix}$$ for any X: (15%)

(c) Find the inverse of the matrix $\begin{bmatrix} 3 & 1 & 3 & 0 \\ 2 & 1 & -1 & 1 \\ 0 & 0 & 5 & 2 \\ 0 & 0 & 3 & 1 \end{bmatrix}$

4. (a) Find the eigenvalues of $\begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$

(b) The equations $\begin{cases} 3x - y = 4 \\ x + 2y = 0 \\ 2x + y = 1 \end{cases}$ have no solution. Find the vector $Z = \begin{bmatrix} x_0 \\ y_0 \end{bmatrix}$ that best approximates a solution. (10%)

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所別：電子與資訊工程技術研究所
科目：工程數學

5. Suppose a sequence of number $x_0, x_1, x_2, \ldots$ is determined by the condition that $x_0 = x_1 = 1$, and each successive x_n is given by
$x = 6x_n + x_{n+1}; \quad n \geq 0$.
Find a formula for x_n in terms of n. (10%)

6. Find the standard matrix of the following linear transformations $R^2 \to R^2$.
(a) Rotation R_θ about the origin through the angle θ.
(b) Projection P_m on the line $y = mx$.
(c) Reflection S_m in the line $y = mx$. (15%)

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所別：電子與資訊工程技術研究所
科目：計算機概論（乙組）〔專業科目一〕

1. (10%)
(a)What's the main advantage of two's complement representation? (5%)
(b)Why we use layering in computer network design?(5%)

2. (12%)
Explain the following terms: CSMA/CD, HTTP, ISDN

3. (8%)
How many address lines would the following sizes of memories require? Assume that the access unit is byte.
(a) 8K bytes (b) 64K bytes (c) 12K bytes (d) 100K bytes

4. (5%)
Point out the error occurring in the following function,"swap". Note that the function swap is to exchange the values of x and y

```
void swap(int x, int y)
{ int temp;
  temp=x; x=y; y=temp;
}
```

5.(5%)
What's the function of the following program?

```
int F(int x, int y)
{ int i, j, k;
  k=0;
  for (i=x; i>0; i--)
  {for (j=y; j>0; j--) k++;}
  return k;
}
```

6.(10%)
(a)What is the Huffman's codes?(5%)
(b)Show that the Huffman's codes can be obtained by using the greedy method.(5%)

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所別：電子與資訊工程技術研究所
科目：計算機概論

7.(16%)
Define the fibinocci numbers as follows:
fib(0)= 1; fib(1)= 1; fib(n)= fib(n-1) + fib(n-2), for n=2,3,...
(a) Define a recursive procedure to compute the function. Trace the computation of fib(4). What is the time complexity of your algorithm? (8%)
(b) Define a non-recursive procedure to compute the function. Trace the computation of fib(4). What is its time complexity of your algorithm? (8%)

8.(10%)
Describe what a topological sort is. Write an algorithm to perform topological sort on a directed acyclic graph. Given a directed graph G with nodes {a,b,c,d,e,f,g} and edges {(a,b), (a,d), (b,c), (b,e), (d,c), (e, f), (g, d)}. Trace your algorithm with this graph.

9.(14%)
Give the definitions of a binary search tree and a 2-3 tree. Show a non-trivial example for each definition. Describe the concept of Abstract Data Type (ADT). The ADT "table" uses a search key to identify its items. What are the advantages of implementing the ADT table with a 2-3 tree instead of a binary search tree? Why do you not, in general, maintain a completely balanced binary search tree?

10.(10%)
Give the definition of a binary heap. Write an algorithm to insert an element into a heap. Trace your algorithm with the input 10, 12, 1, 14, 6, 5, 8, 15, 3. Write a linear-time algorithm to build a binary heap. Trace your algorithm with the same input.

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所別：電子與資訊工程技術研究所
科目：微分方程

1. Find the general solution of the following differential equation: **(20%)**

$$x^3y'''-3x^2y''+6xy'-6y=\ln x$$

2. Solve the following differential equation: **(10%)**

$$y''+y=x\sec x$$

3. Find the general solution of the following differential equation: **(20%)**

$$y'''-3y''+3y'+y=e^x\ln x$$

4. Find $x(t)$ and $y(t)$ of the following system of differential equations: **(20%)**

$$x''=2y+4e^t$$
$$y''=2x-4e^t$$

5. Find the general solution of the following differential equation by using the power series method: **(10%)**

$$y'-2xy=0$$

6. Solve the partial differential equation $\frac{\partial^2 u(x,t)}{\partial t^2}=4\frac{\partial^2 u(x,t)}{\partial x^2}$ which has the two boundary conditions $u(0,t)=0$ and $u(a,t)=0$, for all t and has the two initial conditions $u(x,0)=4$ and $\left.\frac{\partial u(x,t)}{\partial t}\right|_{t=0}=6$ for all x. **(20%)**

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八十六學年度研究所碩士班入學考試試題　科目：離散數學

10 points 1. Write each of the following statements in the form "if p, then q".
(a) That the Pistons win the championship implies that they beat the Lakers.
(b) To get tenure as a professor, it is sufficient to be world-famous.

10 points 2. Show that if S is a finite set with n elements, than S has 2^n subsets.

15 points 3. Show that $2x + \log_2 x$ is O(x).

15 points 4. How many times will the innermost loop be iterated when the following algorithm segment is implemented and run?

```
for k := 1 to n
    for j := 1 to k
        for i := 1 to j
            [the body of the inner loop]
        end for i
    end for j
end for k
```

10 points 5. Let $f: Z \to N$, where Z is the set of integers and N the set of natural numbers, be defined by
f(x) = 2x-1 if x>0
f(x) = -2x if x<=0
(a) Prove that f is one-to-one and onto.
(b) Determine f^{-1}.

10 points 6. In how many ways can the 26 letters of the alphabet be permuted so that none of the patterns *have, fun, ok, pi* occurs?

15 points 7. Let G=(V,E) be a loop-free connected undirected graph, and let {a, b} be an edge of G. Prove that {a, b} is part of a cycle if and only if the removal of the edge (the vertices a and b are left) does not disconnect G.

15 points 8. Let F_n denote the *nth* Fibonacci number. Prove that $\sum_{i=1}^{2n} F_i F_{i-1} = F_{2n}^2$

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八十六學年度研究所碩士班入學考試試題

所別：電子與資訊工程技術研究所
科目：通信系統

1. (10%) Prove that

$$\int_{-\infty}^{\infty} |x(t)|^2 dt = \int_{-\infty}^{\infty} |X(f)|^2 df$$

where $X(f)$ is the Fourier transform of $x(t)$.

2. (a) (5%) The Hilbert transform operator has an equivalent time-domain impulse response given by

$$h(t) = \frac{1}{\pi t}$$

What is the frequency response of this system?

(b) (10%) Find the Hilbert transform of the signal

$$s(t) = \frac{\sin t}{t} \sin(200\pi t).$$

3. (a) (5%) What is the advantage of the Vestigial-Sideband (VSB) AM system as compared to the SSB AM system?

(b) (5%) Draw the block diagram of a VSB AM signal generator.

(c) (5%) Draw the block diagram of a VSB AM demodulator.

4. (15%) The message signal $m_f(t)$ into an FM modulator with frequency deviation constant $k_f = 10$ is

$$m_f(t) = 10\ cos(20\pi t).$$

(a) Find the maximum frequency deviation in the FM system.

(b) Find the effective bandwidth of the modulated signal by using the Carson's rule.

(c) Find the message signal $m_p(t)$ for the equivalent PM modulator with phase deviation constant $k_p = 5$.

5. (15%) Consider the design of the (7,3) binary cyclic code ($n = 7,\ k = 3$) based on the following polynomial factorization:

$$X^7 + 1 = (X+1)(X^3 + X^2 + 1)(X^3 + X + 1).$$

(a) Find the generator polynomial $g(X)$ for each of the possible (7,3) cyclic codes.

(b) Design a systematic (feedback register) encoder for each of the possible (7,3) codes.

(c) Is $(1 + X + X^2 + X^4 + X^6)$ a valid codeword polynomial? Explain.

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所別：電子與資訊工程技術研究所
科目：通信系統

6. (20%) Consider an M-ary digital modulator with five signals $\{s_m(t),\ m = 1,\ldots,5,\ 0 \le t \le T\}$, where $M = 5$ and the duration of each signal, T, is equal to 8. The channel is an additive white Gaussian noise (AWGN) channel, and the optimal coherent demodulator is noted to be the minimum-distance receiver.

$$s_m(t) = \begin{cases} 4\ cos(\omega_c t + \frac{m}{2}\pi), & m = 1,2,3,4, \\ 0, & m = 5, \end{cases} \quad 0 \le t \le 8.$$

(Assume $\omega_c T = 2k\pi,\ \ k \in \{1,2,3,...\}$.)

(a) Find the orthonormal basis functions $\{\psi_j(t),\ j = 1,\ldots,N\}$ for the five signals, where N is the dimension of the signal space.

(b) Find the signal constellation $\underline{s}_m,\ m = 1,\ldots,5$ (i.e., the vector representation of $s_m(t)$ in the signal space).

(c) Find the minimum distance (d_{min}) for this modulation scheme.

(d) Sketch the decision regions $R_m,\ m = 1,\ldots,5$, for the minimum-distance receiver.

(e) Sketch the (optimal) coherent demodulator with reference signals $\{s_m(t),\ m = 1,\ldots,5\}$.

7. (10%) Consider an input $s(t) = \sum_{n=-\infty}^{\infty} a_n \delta(t-n)$ to a linear time-invariant filter with transfer function $H(f) = \begin{cases} 1-|f|, & |f| \le 1, \\ 0, & |f| \ge 1 \end{cases}$, where $a_n \in \{-1,1\}$. By sampling the output of the filter every second, we obtain y_n.

(a) Find the impulse response, $h(t)$, of the filter.

(b) Does y_n have intersymbol interference (ISI)? Explain.

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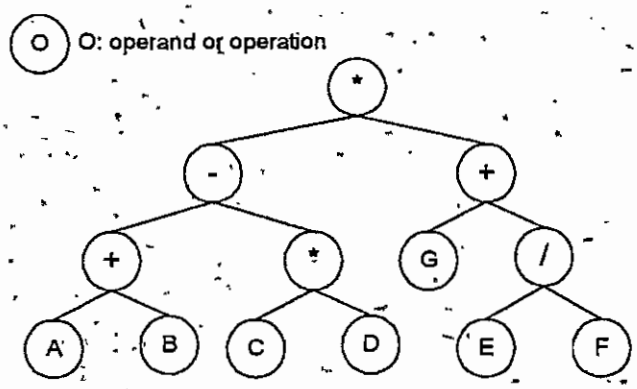
所別：電子與資訊工程技術研究所
科目：計算機概論（甲組）[專業科目三]

1. Consider a tree structure shown below (20 pts)



a. Please define the data structure for each node in the tree so that each node can visit all its parents and children [7 pts]

b. Please write a recursive function which will return all the descent nodes (direct as well as indirect) of a particular node. [6 pts]

c. Please write a recursive function to evaluate the tree value in in-order. [6 pts]

Note: You may use whatever language you feel comfortable to do the coding

2. Please explain and give assembly instruction examples for the following types of addressing modes: (15 pts)

a. Register
b. Immediate
c. Direct
d. Indirect
f. Relative

Note: You may choose any familiar assembly language. However, please indicate the appropriate fields in your example.

3. A special-purpose processor has been designed for a certain signal-processing application. It is a 40-bit processor and performs single-precision, floating-point mathematical operations. The floating-point format consists of a sign bit, a 29-bit unsigned fractional mantissa in normalized form, a 10-bit excess 512 exponent, and base 2 for the exponent. (15 pts)

a. What are the largest positive and negative numbers that can be represented?

b. Find the distance between any two consecutive numbers.

c. Flowchart the algorithm required to add two of these numbers. Assume that the addend and augend are initially stored in RAM and that the sum is to be stored in RAM.

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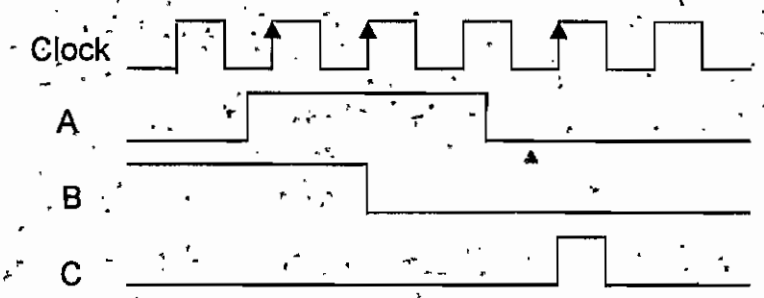
所別：電子與資訊工程技術研究所
科目：計算機概論（甲組）〔專業科目三〕

4. Hierarchical design of priority encoder (15 pts)

A 4-bit priority encoder takes four input bits $D_3D_2D_1D_0$ and produces three output bits, 2-bit XY as encoded output and 1-bit V as valid bit. Please use 4-bit priority encoders and 4-to-1 multiplexers to implement a 16-bit priority encoder which takes $D_{15}D_{14}\cdots D_1D_0$ as input and produce a 4-bit output $C_3C_2C_1C_0$.

5. Please design a circuit which implements the following timing diagram (15 pts)



a. signal A is sampled at every rising edge of the clock

b. for the second clock rising edge after 0 to 1 transition of signal A, signal B is triggered and toggle its state

c. for the first clock rising edge after 1 to 0 transition of signal A, signal C is set to 1 for one clock period and then returns to 0

6. A toggle (or T) flip-flop has a single data input T. Applying T =1 to this flip-flop causes it to change the output (stored state) once in every clock cycle; T = 0 is the quiescent condition. (20 pts)

a. Based on the Huffman method of asynchronous circuit design, construct a flow table for the positive edge-triggered T flip-flop. [7 pts]

b. Give a state assignment for this flow table that is free of critical races. [6 pts]

c. Describe how to modify a T flip-flop to make it into a JK flip-flop. [6 pts]

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所別：電子與資訊工程技術研究所
科目：計算機結構

1. Design a TLB and cache system as follows. Both of the virtual address and physical address are 32-bit wide. The page size is 8 K bytes. The TLB is 4-way set associative and contains 16 entries in total. The cache is physically addressed and direct-mapped. The cache line size is 32 bytes and each line uses the MESI state. The cache has 1024 lines (blocks). The cacheable memory space is 4GB. Show the organization of the TLB and the cache memory and indicate how the address and data lines are used in the TLB, cache, and between the TLB and the cache. (20 pts)

2. Here is a string of address references given as word addresses: 32, 4, 8, 5, 20, 17, 19, 56, 9, 11, 4, 43, 5, 9 ,17. Considering a direct mapped cache with 8 one-word lines (blocks) that are initially empty, label each reference in the address list as a hit or miss and show the final contents of the cache. (20 pts)

3. Computer arithmetic problems: Divide 0011 by 10.
   a. Show the block diagram of the hardware required to perform the operation. (Both 0011 and 10 are binary numbers.) (10 pts)
   b. Show the division algorithm and the content of the registers you used in each of the iterations. (10 pts)

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所別：電子與資訊工程技術研究所
科目：計算機結構

4. A CISC processor has the following instructions:

```
add  [r1], r2          ; memory [r1]  <=  memory [r1] + r2
mov  r1, r2            ; r1  <=  r2
sub  r1, disp(r2)      ; r1  <=  r1 - memory [disp + r2]
mov  r1, disp(r2)      ; r1  <=  memory [disp + r2]
```

Design a set of RISC-type instructions and represent each of the above CISC instructions with one or several RISC instructions so that the RISC instructions perform the same operation as the CISC instruction. You must define the operation of each of the RISC instructions you use in register-transfer level representation. (20 pts)

5. Describe the operation of moving a block of data from disk to memory using the following two approaches respectively. (20 pts)
   a. Programmed I/O using interrupts
   b. DMA I/O

   (Hint: The answer is best given by pointing out 1) the sequence of moving the data and 2) how the hardware interface signals are used.)

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所別：電子與資訊工程技術研究所
科目：系統程式

1. (10%)
How is the forward reference problem solved by a one-pass assembler?

2. (10%)
Describe two methods for specifying relocation information in the object program.

3. (20%)
In each of the following problems, determine whether it is True or False(2%) and give your reason(2%).
(a) A 8086/8088 assembler must be implemented using the 8086/8088 assembly language.
(b) Macro processors are machine independent but language dependent.
(c) In order to make the object code relocatable we must not compile modules of program separately.
(d) There is no difference between a literal and an immediate operand.
(e) The two sentences I:=3+5 and I:=3.0+5.0 have identical semantics but different syntax.

4. (20%)
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	3
P_4	1	4
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. What is the turnaround time of each process for FCFS, SRTN (i.e. SJF), nonpreemptive priority (a smaller priority number implies a higher priority), and RR (quantum=1) scheduling algorithms ?

5. (20%)
Consider the following page reference string:
1, 2, 3, 4, 2, 1, 5, 6, 2, 1, 2, 3, 7, 6, 3, 2, 1, 2, 3, 6
How many page faults would occur for the following replacement algorithms, assuming one, two, three, four, five, six, or seven frames? Remember all frames are initially empty, so your first unique pages will all cost one fault each.
(a) LRU replacement [7%]
(b) FIFO replacement [6%]
(c) Optimal replacement [6%]

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所別：電子與資訊工程技術研究所
科目：系統程式

6. (20%)
Suppose that the head of a moving-head disk with 200 tracks, numbered 0 to 199, is currently serving a request at track 143 and has just finished a request at track 125. The queue of requests is kept in the FIFO order:

86, 147, 91, 177, 94, 150, 102, 175, 130.

Show the head movement needed to satisfy these requests for the following disk-scheduling algorithms?

(a) FCFS scheduling
(b) SSTF scheduling
(c) SCAN scheduling
(d) LOOK scheduling
(e) C-SCAN scheduling.

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所別：電子與資訊工程技術研究所
科目：電磁學

說明：本試卷共五大題，總分共計１００分。

(20%) 1. An electric charge Q, as shown in Fig.1, is located at a distance d from two grounded infinite conducting planes intersecting at right angles. Determine
(a) the electric potential at all points in space, (10%) and
(b) the electric force at point (d, d). (10%)

(20%) 2. A volume charge density $\rho = k/r$ for spherical distances $a<r<b$ and $\rho = 0$ for other r values, where k is a constant. Find the associated electric field for
(a) $r < a$, (6%) (b) $a < r < b$, (7%) (c) $r > b$. (7%)

(20%) 3. A d-c voltage V_o is applied between the inner and outer conductors of a coaxial cable of length L, as shown in Fig.2. The radius of the core and the inner radius of outer conductor are a and c, respectively. The space between the conductors is filled with two layers of lossy dielectric medium with leakage conductivities σ_1 and σ_2, respectively. The boundary surface between layers has radius b. Neglect fringing. Determine the leakage resistance of the coaxial cable.

(20%) 4. A d-c current I = 20 (A) flows in a triangular loop in the xy-plane as shown in Fig.3. The dimensions are in (cm). Assuming an uniform magnetic flux density $\mathbf{B} = \mathbf{a}_y 2$ (T) in the region, where T stands for telsa. Find
(a) the magnetic forces $\mathbf{F}_{AB}$, $\mathbf{F}_{BC}$, and $\mathbf{F}_{CA}$, (12%) and
(b) the torque $\mathbf{T}$ on the loop. (8%)

(20%) 5. Find the self-inductance L per unit length of a transmission line that consists of two coaxial cylinders of radius R_1 and R_2 ($R_1 < R_2$). The space between the two conductors is filled with a substance having absolute permeability μ.

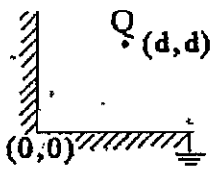

Fig.1.

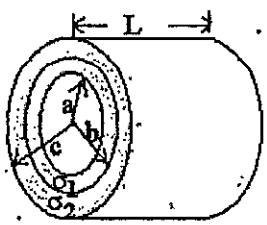

Fig.2.

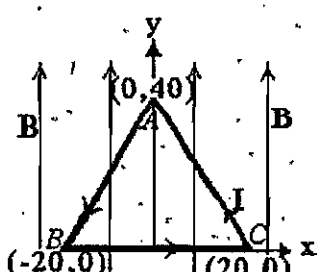

Fig.3.

國立雲林技術學院
八十六學年度研究所碩士班入學考試試題

所別：電子與資訊工程技術研究所
科目：半導體元件

1. What are the two collision mechanisms that dominate in a semiconductor and affect the carrier mobility, please describe in details as a function of temperature. (15%)

2. Please (a) plot (6%) and (b) describe the carrier concentration and conductivity of a semiconductor as a function of temperature for a particular doping concentration(14%).

3. (a) From a particle confined in a box, derive the Schrodinger's wave equation. (10%)
   (b) What is the physical meaning of the Schrodinger's wave equation. (5%)

4. Plot the minority carrier distribution through a uniformly doped $n^{++}p^{+}n$ bipolar transistor for (a) the forward-active mode (7%), and (b) B-E junction forward-biased and collector open (8%).

5. A MOS capacitor with an aluminum gate has a silicon dioxide thickness of 500Å on a p-type silicon substrate doped with an acceptor concentration of $N_a = 10^{15}$ cm^{-3}. Determine the low frequency capacitance per unit area (a) in accumulation condition (5%), (b) at threshold inversion point, where the capacitance is minimum (5%), and (c) in strong inversion condition (5%). Neglect the trapped charge in the oxide and at the oxide-semiconductor interface. $T = 300$ K.

6. A MOSFET with aluminum gate is fabricated on a p-type silicon substrate with $N_a = 10^{15}$ cm^{-3}. The oxide thickness is $t_{ox} = 500$ Å. Assume that an equivalent trapped charge per unit area $Q'_{ss} = 1.6\times10^{-9}$ coul/cm^2 is located in the oxide directly adjacent to the oxide-semiconductor interface. Calculate (a) the threshold voltage (10%), and (b) I_D(sat) at $V_{GS} = 5$ volts (10%) with the following parameters.

   metal-semiconductor work function difference $\phi_{ms} = -0.89$ volts
   $W = 20$ μm $\mu_n = 600$ cm^2/V-sec
   $L = 2$ μm $T = 300$ K

Physical constants	
Avogadro's number	$N_A = 6.02 \times 10^{+23}$ atoms per gram molecular weight
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ J/K $= 8.62 \times 10^{-5}$ eV/K
Electronic charge (magnitude)	$e = 1.60 \times 10^{-19}$ C
Free electron rest mass	$m_o = 9.11 \times 10^{-31}$ kg
Permeability of free space	$\mu_o = 4\pi \times 10^{-7}$ H/m
Permittivity of free space	$\varepsilon_o = 8.85 \times 10^{-14}$ F/cm $= 8.85 \times 10^{-12}$ F/m
Planck's constant	$h = 6.625 \times 10^{-34}$ J-s $= 4.135 \times 10^{-15}$ eV-s
	$\frac{h}{2\pi} = \hbar = 1.054 \times 10^{-34}$ J-s
Proton rest mass	$M = 1.67 \times 10^{-27}$ kg
Speed of light in vacuum	$c = 2.998 \times 10^{10}$ cm/s
Thermal voltage ($T = 300°K$)	$V_t = \frac{kT}{e} = 0.0259$ volt $kT = 0.0259$ eV

Silicon, gallium arsenide, and germanium properties ($T = 300°K$)

Property	Si	GaAs	Ge
Atoms (cm^{-3})	5.0×10^{22}	4.42×10^{22}	4.42×10^{22}
Atomic weight	28.09	144.63	72.60
Crystal structure	Diamond	Zincblende	Diamond
Density (g/cm^{-3})	2.33	5.32	5.33
Lattice constant (Å)	5.43	5.65	5.65
Melting point (°C)	1415	1238	937
Dielectric constant	11.7	13.1	16.0
Bandgap energy (eV)	1.12	1.42	0.66
Electron affinity, χ, (volts)	4.01	4.07	4.13
Effective density of states in conduction band, N_c, (cm^{-3})	2.8×10^{19}	4.7×10^{17}	1.04×10^{19}
Effective density of states in valence band, N_v, (cm^{-3})	1.04×10^{19}	7.0×10^{18}	6.0×10^{18}
Intrinsic carrier concentration (cm^{-3})	1.5×10^{10}	1.8×10^{6}	2.4×10^{13}

Property	Si	GaAs	Ge
Mobility ($cm^2/V\text{-}s$)			
Electron, μ_n	1350	8500	3900
Hole, μ_p	480	400	1900
Effective mass, $\left(\frac{m^*}{m_0}\right)$			
Electrons	$m_l^* = 0.98$	0.067	1.64
	$m_t^* = 0.19$		0.082
Holes	$m_{lh}^* = 0.16$	0.082	0.044
	$m_{hh}^* = 0.49$	0.45	0.28
Effective mass (density of states)			
Electrons, $\left(\frac{m_n^*}{m_0}\right)$	1.08	0.067	0.55
Holes, $\left(\frac{m_p^*}{m_0}\right)$	0.56	0.48	0.37

Other semiconductor parameters

Material	E_g (eV)	a (Å)	ϵ_r	χ	$\bar{n}$
Aluminum arsenide	2.16	5.66	12.0	3.5	2.97
Gallium phosphide	2.26	5.45	10	4.3	3.37
Aluminum phosphide	2.43	5.46	9.8		3.0
Indium phosphide	1.35	5.87	12.1	4.35	3.37

Properties of SiO_2 and Si_3N_4 ($T = 300°K$)

Property	SiO_2	Si_3N_4
Crystal structure	[Amorphous for most integrated circuit applications]	
Atomic or molecular density (cm^{-3})	2.2×10^{22}	1.48×10^{22}
Density ($g\text{-}cm^{-3}$)	2.2	3.4
Energy gap	≈9 eV	4.7 eV
Dielectric constant	3.9	7.5
Melting point (°C)	≈1700	≈1900