第一部份：線性代數

Part I: Multiple Choice Problems（單選題）

Select the best answer for each problem. Each correct answer is awarded 3 points. Each wrong or no answer is awarded 0 point.

1. (3%) Which equation is linear ?

   (a) $\sin(x) - \log(y) = 4$.

   (b) $y = \sqrt{3}x + 1$.

   (c) $x - y^3 = 4$.

   (d) $5^y = x + 1$.

   (e) $xy = 1$.

2. (3%) Gaussian-Jordan elimination can be applied to a matrix to produce a matrix in row-echelon form. Which of the following matrices is in row-echelon form ?

   (a) $\begin{bmatrix} 1 & 2 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}$ (b) $\begin{bmatrix} 2 & 1 & -1 \\ 1 & 2 & 1 \\ -1 & 1 & 2 \end{bmatrix}$ (c) $\begin{bmatrix} 1 & 1 & -1 \\ 0 & 2 & 1 \\ 0 & 0 & 2 \end{bmatrix}$ (d) $\begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ (e) $\begin{bmatrix} 1 & 3 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

3. (3%) Which of the following matrices is a linear combination of $\begin{bmatrix} 3 & -1 \\ 5 & 2 \end{bmatrix}$ $\begin{bmatrix} -1 & 0 \\ 2 & 1 \end{bmatrix}$ and $\begin{bmatrix} 2 & 1 \\ 0 & 3 \end{bmatrix}$?

   (a) $\begin{bmatrix} 2 & 3 \\ -4 & 4 \end{bmatrix}$ (b) $\begin{bmatrix} 1 & 1 \\ -1 & 1 \end{bmatrix}$ (c) $\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$ (d) $\begin{bmatrix} -4 & 6 \\ -13 & 4 \end{bmatrix}$ (e) $\begin{bmatrix} 3 & -1 \\ 8 & 2 \end{bmatrix}$

4. (3%) Assume that $\mathbf{A}$, an $n \times n$ matrix, is not invertible. Which of the following statements is true ?

   (a) $\mathbf{Ax} = \mathbf{b}$ is consistent for every $n \times 1$ matrix $\mathbf{b}$.

   (b) $det(\mathbf{A}) \neq 0$

   (c) The solution of $\mathbf{Ax} = \mathbf{0}$ is not trivial.

   (d) $\mathbf{A}$ can be expressed as a product of elementary matrices.

   (e) $\mathbf{Ax} = \mathbf{b}$ has exactly one solution for every $n \times 1$ matrix $\mathbf{b}$.

5. (3%) Which of the following linear operators is not one-to-one ?

   (a) A reflection about the line $y = -3x$ in $\mathbf{R}^2$.

   (b) A rotation about the z-axis in $\mathbf{R}^3$.

   (c) A dilation with factor $k > 0$ in $\mathbf{R}^3$.

   (d) A contraction with factor $k > 0$ in $\mathbf{R}^3$.

   (e) An orthogonal projection on the xz-plane in $\mathbf{R}^3$.

6. (3%) Suppose that u, v, and w are vectors such that inner products $\langle \mathbf{u}, \mathbf{v} \rangle = 2$, $\langle \mathbf{v}, \mathbf{w} \rangle = -3$, and $\langle \mathbf{u}, \mathbf{w} \rangle = 5$, and, the norms $||\mathbf{u}|| = 1$, $||\mathbf{v}|| = 2$, and $||\mathbf{w}|| = 7$. The expression $\langle 2\mathbf{v} - \mathbf{w}, 3\mathbf{u} + 2\mathbf{w} \rangle$ equals

   (a) -113

   (b) 8

   (c) -40

   (d) 24

   (e) 90

7. (3%) Let inner product of two matrices $\mathbf{A}$ and $\mathbf{B}$ be equal to the sum of the diagonal entries of $\mathbf{A}^T\mathbf{B}$, i.e., $\langle \mathbf{A}, \mathbf{B} \rangle = \text{trace}(\mathbf{A}^T\mathbf{B})$. Suppose that matrix $\mathbf{A} = \begin{bmatrix} 2 & 1 \\ -1 & 3 \end{bmatrix}$. Which of the following matrices is NOT orthogonal to matrix $\mathbf{A}$?

   (a) $\begin{bmatrix} -3 & 0 \\ 0 & 2 \end{bmatrix}$ (b) $\begin{bmatrix} 1 & 1 \\ 0 & -1 \end{bmatrix}$ (c) $\begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$ (d) $\begin{bmatrix} 2 & 1 \\ 5 & 2 \end{bmatrix}$ (e) $\begin{bmatrix} 3 & 4 \\ 4 & -2 \end{bmatrix}$

8. (3%) Which of the following statements about the matrix $\mathbf{A} = \begin{bmatrix} 3 & 0 & 0 \\ -2 & 7 & 0 \\ 4 & 8 & 1 \end{bmatrix}$ is false ?

   (a) Matrix $\mathbf{A}$ is diagonalizable.

   (b) Matrix $\mathbf{A}$ is expressible as a product of elementary matrices.

   (c) Matrix $\mathbf{A}^T\mathbf{A}$ is invertible.

   (d) The linear system $\mathbf{Ax} = \mathbf{b}$ has exactly one solution for every vector b.

   (e) Matrix $\mathbf{A}$ has nullity 1.

9. (3%) Let $T : \mathbf{R}^2 \rightarrow \mathbf{R}^2$ be the linear operator given by the formula

$$T(x, y) = (2x - y, -8x + 4y).$$

   Which of the following statements is true ?

   (a) The vector (5,0) is in the range of T.

   (b) The vector (1,-3) is in the range of T.

   (c) The vector (5,10) is in the kernel of T.

   (d) The vector (3,2) is in the kernel of T.

   (e) The vector (1,1) is in the kernel of T.

10. (3%) Let the linear transformation $T_A : \mathbf{R}^3 \rightarrow \mathbf{R}^3$ be multiplication by the matrix $\mathbf{A} = \begin{bmatrix} 3 & 0 & 0 \\ -2 & 7 & 0 \\ 4 & 8 & 1 \end{bmatrix}$. Which of the following statements about T_A is false ?

(a) T_A is one-to-one.

(b) The inverse transformation of T_A exists.

(c) The range of T_A is $\mathbf{R}^3$.

(d) The kernel of T_A is the empty set.

(e) The nullity of T_A is 0.

Part II: Calculation Problems

1. (5%) Find the standard matrix for the composition of linear operators in $\mathbf{R}^3$: A dilation with factor 3, followed by a rotation of $\frac{\pi}{6}$ about the y-axis, followed by a reflection about the yz-plane.

2. (5%) Find the nullity and the general solution of the system

$$\begin{cases} 2x_1 - 5x_2 + 2x_3 + 4x_4 + 6x_5 = 0 \\ 3x_1 - 7x_2 + 2x_3 + x_5 = 0 \\ -x_1 + 2x_2 + 4x_4 + 5x_5 = 0 \end{cases}$$

3. (5%) Find a 3×3 matrix $\mathbf{A}$ that has eigenvalues λ=0, 1, and -1 with corresponding eigenvectors $\begin{bmatrix} 0 \\ 1 \\ -1 \end{bmatrix}$, $\begin{bmatrix} 1 \\ -1 \\ 1 \end{bmatrix}$, and $\begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$, respectively.

4. (5%) Find an orthogonal matrix $\mathbf{Q}$ and a lower triangular matrix $\mathbf{L}$ such that

$$\mathbf{QL} = \begin{bmatrix} 1 & -1 \\ 2 & 3 \end{bmatrix}.$$

第二部份：機率

1. (10%) Error-correcting codes can be used to improve the reliable storage or transmission of binary data more efficiently than brute force repetition. For example, in a compact disk, error-correcting codes are used to correct scratches that may occur in the CDs. Let a "bit" be a binary data of 0 or 1 and let a "word" be a sequence of 8 bits. Consider the transmission of data over a binary symmetric channel (BSC) with the bit error being p, independent from bit to bit. Suppose we use an error-correcting code such that it can correct at most one bit in each word. What is the probability of correct decision of each word?

2. (20%) The lifetime X of a device is an exponential random variable with parameter λ. i.e. $f_X(x)=\lambda e^{-\lambda x}, x\geq 0$
   (1). Prove that X has the memoryless property
   (memoryless property: $\Pr\{X>t+h \mid X>t\}=\Pr\{X>h\}$
   (2). Suppose 100 new devices are installed at time $t=0$. Find the probability that all devices are still working at time $t=20$.
   (express your answer in terms of λ.)

3. (10%) A miner is trapped in a mine containing 3 doors. The first door leads to a tunnel that will take him to safety after 3 hours of travel. The second door leads to a tunnel that will return him to the mine after 5 hours of travel. The third door leads to a tunnel that will return him to the mine after 7 hours of travel. If we assume the miner is all times equally likely to choose any one of the door, what is the expected length of time he reaches safety? Hint: Let X denote the amount of time (in hours) until the miner reaches safety and let Y denote the door he initially chooses.
   Find $\mathrm{E}\{\mathrm{X}\mid \mathrm{Y}=y_j\}$ and then use $\mathrm{E}\{\mathrm{X}\}=\sum_{j=1}^{J}\mathrm{E}\{\mathrm{X}\mid \mathrm{Y}=y_j\}\mathrm{P}(\mathrm{Y}=y_j)$

4. (10%) The random variable X and Y have a joint *pdf* given by

$$f_{X,Y}(x,y)=\begin{cases}\frac{2}{x}e^{-2x}, & 0\leq x<\infty,\ 0\leq y\leq x\\ 0, & \textit{otherwise.}\end{cases} \quad (1)$$

   Find $\mathrm{E}\{\mathrm{XY}\}$. Hint: $\int_0^\infty z^n e^{-z}dz=\Gamma(n+1)=n!$

Part I: (18 %) 單選題，答對一題得三分。

1. Let A_c be a fixed amplitude, f_c be the carrier frequency, and, $m(t)$ and $\tilde{m}(t)$ be message signals with bandwidth W. Which of the following statements about the bandpass signal $u(t) = A_c m(t)\cos(2\pi f_c t) - A_c \tilde{m}(t)\sin(2\pi f_c t)$ is false ?

   (a) If $\tilde{m}(t)$ is the Hilbert transform of its message signal $m(t)$, then $u(t)$ is a single sideband AM signal.

   (b) Its bandwidth is equal to W.

   (c) Its lowpass representation is $m(t) + j\,\tilde{m}(t)$.

   (d) If $\tilde{m}(t)$ is 0, then $u(t)$ is a double sideband suppressed carrier AM signal.

   (e) If $m(t)$ and $\tilde{m}(t)$ are two different message signals, then the way to generate $u(t)$ is called quadrature carrier multiplexing.

2. Which of the following functions can be the autocorrelation of a real-valued random process ? The symbol f_c denotes a fixed frequency.

   (a) $f(\tau) = \sin(2\pi f_c \tau)$

   (b) $f(\tau) = \tau^2$

   (c) $f(\tau) = \begin{cases} 1 - |\tau|, & |\tau| \le 1 \\ 0, & |\tau| > 1 \end{cases}$

   (d) $f(\tau) = \tan(2\pi f_c \tau)$

   (e) $f(\tau) = \tau^3$

3. Let X be a real-valued Gaussian random variable with zero mean and unity variance. Which of the following statements is false ?

   (a) $E\{X\} = 0$

   (b) $E\{X^2\} = 1$

   (c) $E\{X^3\} = 0$

   (d) $E\{X^4\} = 1$

   (e) $E\{X^5\} = 0$

4. Consider a set of four binary codewords given by $\mathbf{c}_1 = [1,1,1,1]$, $\mathbf{c}_2 = [1,-1,1,-1]$, $\mathbf{c}_3 = [1,1,-1,-1]$, and $\mathbf{c}_4 = [1,-1,-1,1]$. Assume that the received signal of a receiver is given by $\mathbf{r} = -\mathbf{c}_m + \mathbf{z}$ where $\mathbf{z}$ is a 1×4 zero-mean real-valued Gaussian random vector with $E[\mathbf{z}^T\mathbf{z}] = \sigma^2\mathbf{I}$. Given $\mathbf{r} = [-0.3, 0.2, -0.1, -0.2]$, find the maximum-likelihood codeword.

   (a) $\mathbf{c}_1$

   (b) $\mathbf{c}_2$

   (c) $\mathbf{c}_3$

   (d) $\mathbf{c}_4$

   (e) $\mathbf{c}_1$ and $\mathbf{c}_2$

5. The general representation of a set of M carrier-phase modulated signal waveforms is $u_m(t) = \sqrt{2E/T}\cos(2\pi f_c t + 2\pi m/M)$, for $m = 0, 1, \ldots, M-1$, and $0 \le t \le T$, where f_c is the carrier frequency. Determine the Euclidean distance between $u_m(t)$ and $u_n(t)$.

   (a) $\sqrt{2E\left(1 - \sin\frac{2\pi(m-n)}{M}\right)}$

   (b) $\sqrt{2E\left(1 - \cos\frac{2\pi(m-n)}{M}\right)}$

   (c) $2E\left(1 - \sin\frac{2\pi(m-n)}{M}\right)$

   (d) $2E\left(1 - \sin\frac{2\pi(m-n)}{M}\right)^2$

   (e) $2E\left(1 - \sin\frac{2\pi(m-n)}{M}\right)$

6. Consider M-ary FSK signal waveforms given by $u_m(t) = \sqrt{2E/T}\cos(2\pi f_c t + 2\pi m\Delta f t)$, for $m = 0, 1, \ldots, M-1$, and $0 \le t \le T$, where f_c is the carrier frequency and Δf is the frequency separation between successive frequencies. Define $\gamma_{mn} = (1/E)\int_0^T u_m(t)u_n(t)dt$. Determine γ_{mn}.

   (a) $\gamma_{mn} = \text{sinc}((m-n)\Delta f)$

   (b) $\gamma_{mn} = \sin((m-n)\Delta f)$

   (c) $\gamma_{mn} = \cos((m-n)\Delta f)$

   (d) $\gamma_{mn} = 1 - \sin^2((m-n)\Delta f)$

   (e) none of the above

Part II: (30 %) 解釋名詞，評分將以答題之完整性及正確性為標準。

1. (15 %) Frequency Division Multiplexing
2. (15 %) Eye Pattern

Part III: (52 %) 計算題

1. (13 %) The system shown in Figure 1 is used to generate a conventional AM signal. The modulating signal $m(t)$ has zero mean and its maximum (absolute) value is $A_m = \max|m(t)|$. The nonlinear device has a input-output characteristic

$$y(t) = ax(t) + bx^2(t).$$

(a) (4%) Specify the filter characteristic $h(t)$ or $H(f)$ such that the filter output $u(t)$ is a conventional AM signal.

(b) (5%) What condition should the parameters a, b, and A_m satisfy such that $u(t)$ is a conventional AM signal ?

(c) (4%) Determine the modulation index for the conventional AM signal $u(t)$.

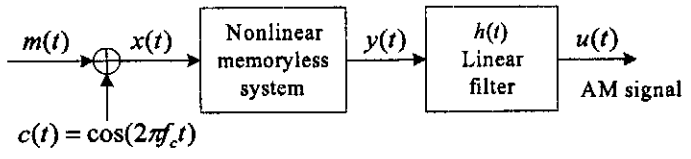


Figure 1

2. (13 %) Let the random signal $X(t)$ be defined by $X(t) = A\cos(2\pi f_0 t + \Theta)$, where A and f_0 denote fixed amplitude and frequency, and, Θ denotes the random phase that is uniform over $[0, 2\pi]$. This random signal $X(t)$ is passed through a LTI system with impulse response $h(t) = \frac{1}{\pi t}$. Determine the power spectral density of the output random signal $Y(t)$.

3. (16 %) The equivalent baseband transmitted signal for a digital communication system is given by

$$V(t) = \sum_{n=-\infty}^{\infty} A_n g(t - nT)$$

where A_n is the complex-valued wide-sense stationary random information sequence and $g(t)$ is the impulse response of the transmission filter. Define $\mu = E[A_n]$ and $R(n) = E[A_m^* A_{n+m}]$.

(a) (3%) Determine the mean $E[V(t)]$.

(b) (5%) Determine the autocorrelation function of $V(t)$.

(c) (6%) Determine the power-spectral density of $V(t)$.

(d) (2%) Is $V(t)$ wide-sense stationary?

4. (10 %) The transmitted signal for a discrete-time binary PAM system is given by

$$u_k = \begin{cases} 2E, & \text{if } m_k = 1 \\ 0, & \text{if } m_k = 0 \end{cases}$$

where m_k is the binary transmitted symbol at time k that is assumed to be an i.i.d. random process with probabilities $P\{m_k = 1\} = P\{m_k = 0\} = 1/2$. The received signal of a receiver is given by

$$r_k = a_k u_k$$

where a_k is an i.i.d. circularly symmetric complex Gaussian random process with $E[|a_k|^2] = 1$. A non-coherent detector is employed to detect the transmitted symbol with the following decision rule

$$\hat{m}_k = \begin{cases} 1 & \text{if } |r_k| > \lambda \\ 0 & \text{if } |r_k| \leq \lambda \end{cases}$$

where λ is a threshold value. Determine the averaged bit error probability $P\{\hat{m}_k \neq m_k\}$ in terms of E and λ.

Part I: (18%) Multiple-choice questions. Please choose the most appropriate answer.

1. (3%) Which of the following statements is correct:
   (a). Slotted ALOHA provides less throughput than ALOHA.
   (b). ALOHA uses binary exponential backoff once collision is detected.
   (c). ALOHA throughput does not depend on the propagation_delay/frame_time ratio.
   (d). CSMA is less efficient than ALOHA because it needs to sense the channel first.
   (e). CSMA/CD is the main MAC mechanism used in GSM system.

2. (3%) Consider a packet from host H1 traverses through router R1 and router R2 to reach host H2.
   (a). As the packet leaves H1, its destination IP address is R2's IP address.
   (b). As the packet leaves R1 and travels to R2, its destination MAC address is R2's MAC address.
   (c). As the packet leaves R2 and travels to H2, its source MAC address is H1's MAC address.
   (d). As the packet passes through R1, its destination MAC address remains the same.
   (e). As the packet leaves R1 and travels to R2, its source IP address is R1's IP address.

3. (3%) In mobile IP,
   (a). Correspondent node contacts the foreign agent to find the mobile host.
   (b). Mobile host obtains care-of address from the home agent.
   (c). Home agent stores correspondent node's address for the mobile node
   (d). Correspondent node sends the packet to mobile host's home address.
   (e). Correspondent node sends the packet to the care-of address of the mobile host because it does know the mobile host's home address.

4. (3%) Which of the followings about PPP is not correct?
   (a). The flag 01111110 is used to signal the beginning and end of a frame.
   (b). The control field is fixed at 0x03.
   (c). It is a data link layer protocol.
   (d). It uses TDMA for medium access control.
   (e). The frame length must be an integer multiple of bytes.

5. (3%) In IEEE 802.11 DCF, the RTS/CTS scheme is used for
   (a). Collision avoidance.
   (b). Reducing the impact of frame collision.
   (c). Saving energy.
   (d). Eliminating the hidden node problem.
   (e). Synchronizing the frames.

6. (3%) For CIDR addressing rule, which are the following network address pairs reside in the same sub-network? _____
   (a). 128.213.176.213/15 and 128.213.176.213/15?
   (b). 192.168.10.8/24 and 192.168.10.2/24?
   (c). 140.140.107.22/10 and 140.128.176.213/10?
   (d). 140.168.10.8/16 and 192.168.10.8/16?

Part II : (82 %) Question-and-Answer questions.

7. (9 %) CSMA/CD and CSMA/CA are two medium access control (MAC) mechanisms.
   (a) Please explain their similarities and differences.
   (b) Which one is used in 802.3 wired Ethernet and which one is used in 802.11 wireless LAN?
   (c) Explain why we cannot use one MAC mechanism for both wired and wireless LAN.

8. (12 %) Suppose that p is the probability that a node will transmit in a slotted ALOHA system.
   (a) If there are two active nodes in the slotted ALOHA system, find the efficiency (or utilization) of the system in terms of p.
   (b) Find the p that maximizes the efficiency in (a).
   (c) What is the resulting maximum efficiency from (b).
   (d) Repeat (a)-(c) if there are N active nodes in the slotted ALOHA system.

9. (10 %) A layer two frame is made up of starting flag, information bits, CRC bits, and ending flag. Suppose the pattern 10000001 is used as the delimiting flag and the CRC generator G is 100011. Bit stuffing is performed by inserting a "1" whenever 5 consecutive "0" occur in the combined "information + CRC" field. If the following bit string is received from the upper layer, what will the resulting frame be (to pass to the physical layer)?

   01000110|00100011|00000010|01101010|000

10. (9 %) Compare the Distance Vector and Link State routing protocols.
    (a) Describe the operation of each protocols
    (b) List two routing protocols for each type
    (c) Describe the advantages and disadvantages for each protocol.

11. (10 %) Describe the functions and compare the difference of SMTP and POP3

12. (10 %) For (a)-(d), please indentify the transport layer protocol (UDP or TCP) for each of the following application protocols. For question (e), please describe your design.

    (a) DNS runs on UDP or TCP?

    (b) Email runs on UDP or TCP?

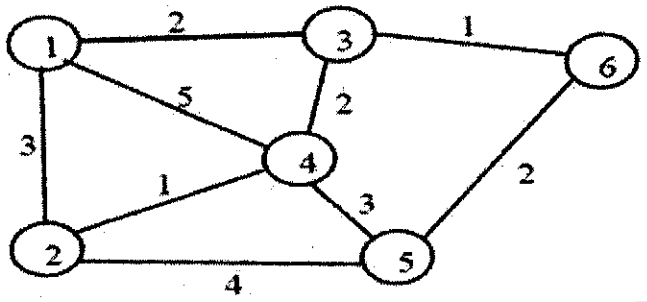
    (c) SNMP runs on UDP or TCP?

    (d) FTP runs on UDP or TCP?

    (e) How to run a reliable service over UDP?

13. (10%) In order to transmit packets efficiently, how does TCP adjust the traffic rate injected into the Internet to avoid congestion? (Hint: how to determine the amount of packets injected into the Internet). Describe the design discipline by explaining the purpose for each term in the formula as well.

14. (12%) Please apply the Dijkstra's algorithm to the following network topology to find the shortest path tree (SPT) rooted at the source node（node 3）.



Iteration	Converged node set	D_{31}	D_{32}	D_{34}	D_{35}	D_{36}
0	{3}	2	∞	2	∞	1
1						
2						
3						

Note : D_{31} denotes the distance from node 3 to node 1. Similarly, the same notations applied on all other nodes.

1. (20 points) The following C program segment defines a structure type `event_t` and a global variable `event_schedule` to constitute a linked list to store a list of events in chronological order. The subroutine `event_get()` picks up an event from the list head. The subroutine `event_insert()` inserts an event into the list in chronological order. Fill the blanks of the subroutine `event_insert()` with five options as follows:

(1) `curr = curr->next;`　　(2) `prev = curr;`

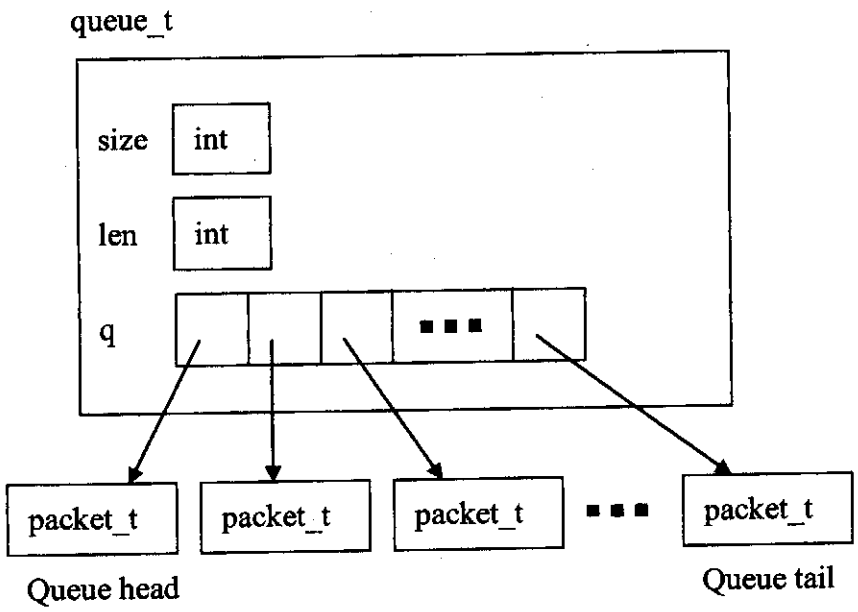
(3) `event_schedule = p;`　　(4) `p->next = curr;`

(5) `prev->next = p;`

```
typedef struct event_t{
  double time;
  struct event_t *next;
}event_t;
event_t *event_schedule;

event_t *event_get() {
  event_t *p = event_schedule;
  if(p) event_schedule = p->next;
  return p;
}
void event_insert(event_t *p) {
   /* p->time must be set a priori */
  event_t *prev = NULL, *curr = event_schedule;
  while(curr) {
    if(p->time < curr->time) break;
    _______(a)_______;
    _______(b)_______;
  }
  _____(c)_____;
  if(prev)
    _______(d)_____;
  else
    _______(e)_____;
}
```

2. (30 points) The following C program segment defines a structure `packet_t`, a structure `queue_t`, and the constant `FULL`. The structure `queue_t` implements a queue containing packets, with length `len` and maximum size `size`. The field "q" is a dynamically allocated array of pointers to those packets. The constitution of packet queue is shown in the figure. You should answer following sub-questions in C language.

```
typedef struct packet_t{
  /* ..... */
}packet_t;

typedef struct queue_t{
  int size;
  int len;
  packet_t **q;
}queue_t;

#define FULL  -1
```



(a) Given a subroutine enqueue as follows, fill the blanks with proper codes.

```
int enqueue(packet_t *p, queue_t *q) {
  if(q->len == q->size)
    return FULL;
  if(p) {
    _____________
    _____________
  }
  return 0;
}
```

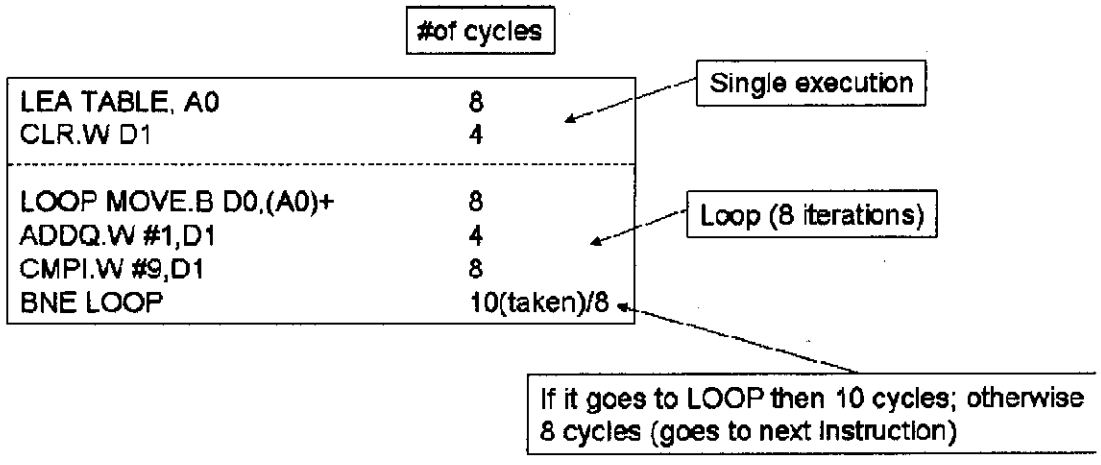
(b) Given a subroutine dequeue as follows, fill the blanks with proper codes. (Hint: you may use memmove(void *dst, const void *src, size_t len) to copy byte string in a non-destructive manner.)

```
packet_t *dequeue(queue_t *q) {
  packet_t *p;
  if(q->len == 0)
    return NULL;
  _____________
  _____________
  _____________
  return p;
}
```

(c) Given global scope declarations of three queues and a queue array of pointers to those queues as follows, finish the code segment to initialize three queues with proper memory space to accommodate packets. (Hint: you may use `malloc()` to allocate memory)

```
queue_t queue1 = {50}, queue2 = {50}, queue3 = {50};
queue_t *queues[] = {&queue1, &queue2, &queue3, NULL};

int main() {
  queue_t **q = queues;
  /* to initialize queues */
  while(*q) {
    if((*q)->q == NULL)
      (*q)->q = _____ ;
    q++;
  }
  /* ..... */
}
```

3. (15 points) There is a program containing the single execution and a loop (8 iterations) execution (as shown below). Answer the following questions: a) Find the total execution time of the given program on a 12.5 MHz microprocessor; b) What is the average CPI (number of clocks per instructions)? c) What is the MIPS rate?



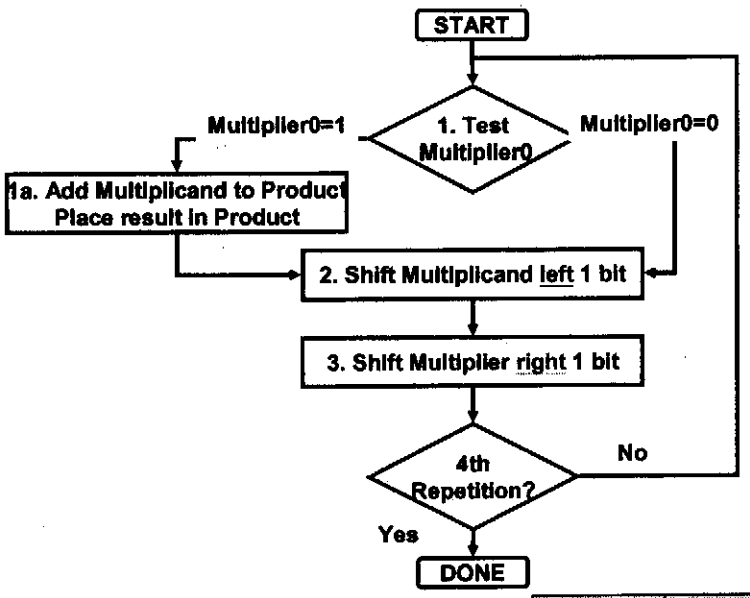
4. (10 points) Fill out the following table to summarize how hardware/software components affect the factors in CPU performance equation. (Use the Yes/No to indicate whether it has impacts or not.)

Factors / Components	Instruction Count	CPI	Clock Rate
Algorithm			
Programming Language			
Compiler			
ISA			

5. (15 Points) Make right connections for the pipeline hazards and solutions.

Structural hazards	Reordering Instructions
	Forwarding
Control hazards	Delayed branch
	Stall
Data hazards	Predict

6. (10 points) Trace the multiplication algorithm (as shown in the following pictures) and show the output on the iteration table. *Multiplier0* stands for the value of Multiplier at the bit 0 position.



Iteration	Multiplier	Multiplicand	Product
0	0011	0011	0000 0000
1			
2			
3			
4			