

Ritsumeikan University Graduate AY2025 Entrance Examination

Master's Program

Graduate School of Information Science and Engineering

Advanced Information Science and Engineering Major

Admissions	Course	Examination	Major Subjects (Common Subjects・Specialized Subjects)	
			Page	Notes
Regular Admissions (English-based Program)	Information Science and Engineering	August	P.1~	
		February	P.21~	
		February (September 2026 Enrollment)	P.21~	
International Student Admissions (English-based Program)		May (September 2025 Enrollment)		
In-University Advancement Admissions (English-based Program)		November		
		July		
Accelerated Learners (Grade Skippers) (English-based Program)		February (September 2026 Enrollment)		
		February	P.21~	

【How to read the front cover page】

×…Those for which the entrance examination questions were not created due to reasons such as the entrance examination not being conducted, or those for which the examination questions are not disclosed.

Ritsumeikan University Graduate School
AY2025 Entrance Examination

Doctoral Program

Graduate School of
Information Science and Engineering

Advanced Information Science and Engineering Major

Written Examination is not conducted for the Doctoral Program.

August 2025 Admissions

AY2026 Examination Questions for the Graduate School of
Information Science and Engineering, Ritsumeikan University
(Master's Program)

Major in Information Science and Engineering
Information Science and Engineering Course

【How to answer questions】

Please follow the instructions below and answer the questions.

- 1) Choose two questions from question ①~③ for Common Subjects.
 - 2) Choose either the Computer Science section or the Human Information Science section for Specialized Subjects.
 - In case choosing the Computer Science section, answer three questions from question ④~⑨.
 - In case choosing the Human Information Science section, choose one question either ⑩ or ⑪.
- *There will be two blank answer sheets in case choosing the Human Information Science section.

Examination Subjects and Questions		Allocation of Points		Remarks	
Common Subjects	① Linear Algebra	100 points	Total 200 points	Choose 2 out of the 3 questions	
	② Probability and statistics	100 points			
	③ Data structure and algorithms	100 points			
Specialized Subjects	Computer Science	④ Computer Architecture	-	Total 100 points	Choose 3 out of the 6 questions
		⑤ Operating System	-		
		⑥ Software Engineering	-		
		⑦ Computer Networks	-		
		⑧ Databases	-		
		⑨ Artificial Intelligence	-		
	Human Information Science	⑩ Image processing	100 points	Total 100 points	Choose 1 out of the 2 questions
		⑪ Artificial Intelligence	100 points		

【Examination time】

9:30-11:30 (120minutes)

※Leaving the examination venue is not allowed during the examination time.

※In case you feel sick or need to go to the bathroom, let examination supervisors know by raising your hand.

【Notes】

- (1) Use one answer sheet for one question.
- (2) Fill out your examination number and name for all the answer sheets. Also, make sure to fill out all the other necessary sections such as the questions number column.
- (3) Do not remove the staple of your answer sheets.
- (4) Answer sheets with no names will be invalid and the score will be 0 points.
- (5) Do not take the question sheets and answer sheets with you after the examination.

Common Subjects

- ① Linear Algebra
- ② Probability and Statistics
- ③ Data Structure and Algorithms

Choose two questions from the above.

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Common Subjects① Linear Algebra

Answer all the questions below with the derivation process.

Question 1. Solve the following system of equations with the inverse matrix method.

$$\begin{cases} x + 2y + 3z = 3 \\ 5x + y + z = 9 \\ 7x + 3y + 5z = 17 \end{cases}$$

Question 2. Answer the following questions, given matrix $A = \begin{bmatrix} 7 & 5 \\ 1 & 3 \end{bmatrix}$.

- (1) Find the eigenvalues of matrix A .
- (2) Find the eigenvectors of matrix A .
- (3) Answer whether matrix A is diagonalizable and give the reason.

Question 3. Answer the following questions, considering the original basis vectors $e_1 = (1,0)$ and $e_2 = (0,1)$ are rotated by angle θ .

- (1) Find the new basis vectors e'_1 and e'_2 after rotation.
- (2) Given a point $B(a, b)$ in the original basis, find its coordinates with respect to the rotated basis vectors.

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Common Subjects② Probability and Statistics

Answer all the questions below. Make sure to show all calculation steps and explain your reasoning.

Question 1.

The probability density function (PDF) of a continuous random variable X is given by:

$$f(x) = \begin{cases} ax^2, & 0 \leq x \leq 1 \\ 0, & \text{otherwise} \end{cases}$$

Answer the following:

- (1) Find the value of a .
- (2) Find $P\left(X > \frac{1}{2}\right)$
- (3) Find the expected value and variance of X .
- (4) Find the cumulative distribution function (CDF) $F(x)$ of X .

Question 2.

In a certain web system, incorrect login password entries are automatically recorded. According to past statistics, the probability that a user makes a mistake in one login attempt is 0.01. Assume that each user's attempt is independent of the others. Now, suppose 100 users each try to log in once. Answer the following questions. You may refer to the following probability functions and approximations:

For a random variable X that follows a binomial distribution with n trials and probability p :

$$P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}$$

For a random variable Y that follows a Poisson distribution with mean λ :

$$P(Y = k) = \frac{\lambda^k e^{-\lambda}}{k!}$$

Approximations:

$$(1 - 0.01)^{98} \approx e^{-0.98} \approx 0.375$$

$$e^{-1} \approx 0.368$$

- (1) Using the binomial distribution, calculate the probability that exactly 2 users entered the wrong password.
- (2) Approximate the same probability using the Poisson distribution.
- (3) Compare the results from (1) and (2). Briefly explain the conditions under which the binomial distribution can be approximated by the Poisson distribution, and state whether this case satisfies those conditions.

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Common Subjects ③ Data Structure and Algorithms

Answer all the questions below.

Question 1. Figure 1 shows an algorithm that sorts an array A of length n , indexed from 0, in ascending order. Answer the following questions.

- (1) When the function $\text{Sort}(A, 4)$ is executed on the array $A = [6, 5, 2, 3]$, describe the complete contents of the array A after each iteration of the outer for loop (i.e., after $i = 1, 2,$ and 3).
- (2) Give the name of the algorithm shown in Figure 1.
- (3) State the worst-case and best-case time complexities of the algorithm in Figure 1 using order notation in terms of the number of elements n in the array A .
- (4) Provide a specific example of a specific input array of length 4 that minimizes the number of comparisons and assignments performed by the algorithm and briefly explain why this input minimizes them.
- (5) State whether the algorithm in Figure 1 is a stable sorting or not.

```

Procedure Sort(A, n)
  for i ← 1 to n - 1 do:
    key ← A[i]
    j ← i - 1
    while j ≥ 0 and A[j] > key do:
      A[j+1] ← A[j]
      j ← j - 1
    A[j+1] ← key
    
```

Figure 1: Sort algorithm

Question 2. Figure 2 shows an adjacency list representation of an undirected graph $G = (V, E)$. Figure 3 shows a recursive algorithm that performs a depth-first search (DFS) on this graph. Assume that array `visited` keeps track of whether each vertex has been visited, and all elements of `visited` are initially set to `False`. Answer the following questions.

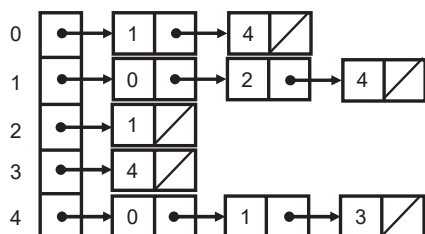


Figure 2: Adjacency list representation of an undirected graph G

```

Procedure DFS(G, visited, v):
  (a) ← True
  print(v)
  for each w in G[v] do:
    if (b) == False then:
      (c)
    
```

Figure 3: Recursive depth-first search algorithm

- (1) Express the space complexity of the adjacency list representation shown in Figure 2 using order notation in terms of the number of vertices n and the number of edges m .
- (2) Represent the graph G in Figure 2 using an adjacency matrix. The rows and columns should be ordered by ascending vertex numbers. Use 1 for adjacent vertices, 0 otherwise, and set all diagonal entries to 0.
- (3) Fill in the most appropriate pseudocode for blanks (a), (b), and (c) in the DFS algorithm Figure 3. Use the same variable names and syntax as shown in Figure 3.
- (4) When executing $\text{DFS}(G, \text{visited}, 0)$ on the graph G in Figure 2, list all the vertex numbers in the order they are printed. Assume that each adjacency vertex's list is processed in ascending order of vertex numbers.
- (5) When converting the recursive implementation in Figure 3 to a non-recursive version, name one representative data structure that be used.

Specialized Subjects

Computer Science

- ④ Computer Architecture
- ⑤ Operating System
- ⑥ Software Engineering
- ⑦ Computer Networks
- ⑧ Databases
- ⑨ Artificial Intelligence

In case choosing the Computer Science section, answer three questions from question ④～⑨

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Computer Science④ Computer Architecture

Answer all the questions below.

Question 1.

Fill in the blanks through in the following sentences regarding the IEEE 754 floating-point standard with the appropriate word(s), value(s), or equation. Assume that the same word is filled in the blanks with the same symbol.

When expressing the real number 1.0 in the single-precision floating-point format of the IEEE754 standard, the value of each bit is as shown in Figure 1. Bit 31 is called the bit, bits from 30 to are called the field, and the remaining bits are called the field.

Bit position	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value of each bit	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Figure 1.

In the single-precision floating-point format, let s be the value of the bit, x be the value of the bit sequence in the field considered as an unsigned binary number, and z be the value of the binary fractional number $0.y$, where y placed after the decimal point is the bit sequence in the part. When $1 \leq x \leq \text{$, this floating-point format expresses numbers in a(n) form. The value it represents can be expressed as an equation using s , x , and z , and is given as

$$(-1)^s \cdot (\text{$$

For example, in Figure 1, $s=0$, $x=\text{$, and $z=\text{$, so the value it represents is 1.0. The value represented by single-precision floating-point format in Figure 2 is .

The single-precision floating-point format for representing 1.0×2^{30} is $s = 0$, $x = \text{$, $z = \text{$. The value obtained by adding 1.0 to 1.0×2^{30} is expressed in single-precision floating-point format as $s = 0$, $x = \text{$, $z = \text{$.

Bit position	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value of each bit	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Figure 2.

Question 2.

Fill in blanks through in the following sentences regarding memory elements and storage medium with the appropriate word(s). Assume that the same word is filled in the blanks with the same symbol.

Memory elements can be broadly divided into non- and memory, depending on whether they require a power supply to retain memory. An example of the former is , which is widely used as built-in storage in mobile PCs and tablet devices. Examples of the latter include , which is used as the main memory device of computers, and , which is used as cache memory. One of the important performance indicators of a memory element is the time, and generally has a shorter time than .

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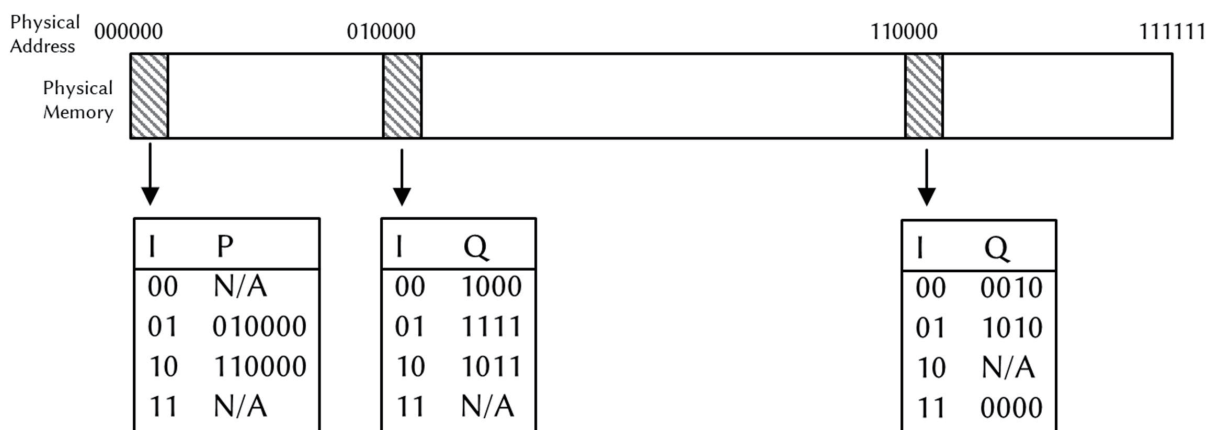
Computer Science⑤ Operating System

This question consists of 2 pages. Answer all the questions below.

Consider a system with a virtual memory that translates virtual addresses to physical addresses by 2-staged page tables. A virtual address A_v and a physical address A_p are each 6 bits long, and a virtual address space is divided into pages that are 4 bytes each in size. A virtual address A_v is split into 3 parts. The 1st to 2nd bits indicate the index I_1 of the 1st-stage page table, the 3rd to 4th bits indicate the index I_2 of the 2nd-stage page table, and the 5th to 6th bits indicate the in-page offset D , where the left-most bit of an address is referred to as the '1st bit'. A virtual address A_v is translated to the corresponding physical address A_p as follows.

1. The I_1 -th entry from the head of the 1st-stage page table is referenced. The number in the entry is referred to as P . P indicates the physical address of the head of the 2nd-stage page table.
2. The I_2 -th entry from the head of the 2nd-stage page table is referenced. The number in the entry is referred to as Q .
3. The physical address A_p corresponding to A_v is calculated by $(Q \ll 2) + D$, where \ll is a logical left shift operation.

Now we have page tables for a process as illustrated in the figure below. The 1st-stage page table of this process is stored at physical address 0. Note that the numbers in the figure are shown as binary numbers and N/A indicates that there is no value in that entry.



Question 1. Translate the virtual addresses below to the corresponding physical addresses. Answer N/A if there is no corresponding physical address for a given virtual address.

- (1) 100000
- (2) 101111
- (3) 000000
- (4) 010101

Question 2. Answer the following questions on the efficiency of this virtual memory.

- (1) Answer the number of pages that a virtual address space contains in this system.
- (2) Consider a system with virtual memory with 1-staged page tables that achieve the same virtual-to-physical address mappings as in the figure. In this system, the 1st to 4th bits are used as the index for referencing a page table entry, and the physical address is given as $(R \ll 2) + D$, where R is the number in the referenced entry. Answer the number of entries that the page table needs to have.
- (3) Answer the number of accesses to page tables needed to translate a virtual address to a physical address. Answer separately for 2-staged page tables and 1-staged page tables.

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Question 3. Modern systems often have page tables of many stages such as 4 or 5. Answer 'true' or 'false' for each of the following statements. Answering 'true' to all the statements or answering 'false' to all the statements will result in 0 points for Question 3. The 'last stage page table' in (1) refers to the page table accessed at the end of a translation process of a virtual address to a physical address.

(1) Let the number of entries of the last stage page table be S_N , where N is the number of stages of page tables. Then $S_5 \leq S_4$ holds. Here, the bit-width of the virtual addresses and the size of the pages are unchanged.

(2) The number of stages of the page tables for a given system is uniquely determined by the bit-width of a physical address in the system.

(3) The number of stages of page tables and the bit-width of the index of each stage are defined by the MMU. Some hardware provide multiple choices, where the OS or applications can choose one according to their needs.

(4) Increasing the number of stages of the page tables results in a larger number of accesses to the page tables for each address translation. However, the slowdown incurred by this larger number of accesses can be mitigated by caching a part of the page tables inside the MMU.

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Computer Science⑥ Software Engineering

Please answer all the following four questions.

Question 1.

Describe the difference between requirements and requirements specification.

Question 2.

Describe a situation where adaptive software maintenance is conducted.

Question 3.

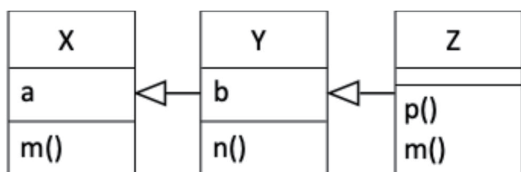
In software testing, explain the drawbacks of adopting each of the following two types of logical coverage criteria.

(1) Statement coverage (C0)

(2) Branch coverage (C1)

Question 4.

Describe all attributes and operations that an instance of the class Z has in the inheritance relationship shown in the class diagram below. If the instance does not have any attributes or operations, write "none."



- Attributes:

- Operations:

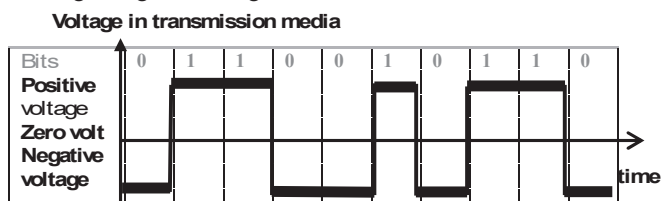
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Computer Science⑦ Computer Networks

Answer all the questions below.

Question1. Answer the following two sub-questions regarding line codes that use positive and negative voltages as physical quantities.

- (1) Describe the two line codes: (Q1a) a return-to-zero line code and (Q1b) MLT-3 encoding.
- (2) Illustrate changes in physical quantities of transmission media such as voltage for bit sequence "0110010110" for each of the two line codes: (Q2a) a return-to-zero line code and (Q2b) MLT-3 encoding. The following is an example of another line code illustrating changes of voltage for reference.



The example illustrates changes of voltage for bipolar non-return-to-zero level (NRZ-L) with 0-bit assigned to negative voltage. The line code is the bold line part. The vertical dotted lines indicate the transmission clock rise time.

Question 2. For the descriptions regarding computer networks from (1) to (7), complete each description by selecting the correct answers from the options inside the rectangles. Or you may answer by writing appropriate keywords or phrases if you find no suitable options. Assume that the same option should be assigned to the rectangles with the same question identification in the descriptions.

- (1) The abbreviation in English for the specialized agency of the United Nations that promotes international standardization and regulation in the fields of wireless and telecommunications is: Q(a) ① ITU ② IETF ③ IEEE ④ IrDA .
- (2) In the LAN standard FDDI, a special frame called Q(b) ① Carrier ② Segment ③ Collision ④ Token circulates from node to node to control transmission rights. A node that wants to transmit gains the right to do so when it receives the Q(b) . In principle, collisions in FDDI Q(c) ① are unavoidable ② do not occur ③ occur only between adjacent nodes .
- (3) In the OSI Basic Reference Model (also known as the OSI Reference Model), the layer that transfers bits using transmission media such as electrical signals or light is the Q(d) layer. Furthermore, in the Session Layer, the following functions may be performed: Q(e) ① Dialogue control between application processes ② Conversion from abstract syntax to transfer syntax ③ Specification of optical fiber ④ Routing control .
- (4) For the IPv4 address 172.24.32.66 written in dotted decimal notation, the IP network belongs to Class: Q(f) ① A ② B ③ C ④ D ⑤ E . If the subnet mask is 255.255.255.192, the broadcast address to be used in this IP network is: Q(g) ① 172.24.255.255 ② 172.24.32.64 ③ 172.24.32.127 ④ 172.24.32.255 .
- (5) Among the IP headers of IPv4 and IPv6, the source IP address field is present in: Q(h) ① IPv4 only ② IPv6 only ③ both IPv4 and IPv6 .
- (6) Among TCP and UDP in IPv4, the header contains a checksum field in: Q(i) ① TCP only ② UDP only ③ Both TCP and UDP .
- (7) The communication protocol that guarantees the quality of communication paths on an IP network by reserving bandwidth in advance from the sender to the receiver is: Q(j) ① RSVP ② RTP ③ RTSP ④ RTCP .

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Computer Science⑧ Database

Answer all the questions below.

Question 1. For the following explanations on relational algebra, fill in the appropriate terms in blanks (1) to (5). Assume that the same term is enclosed in the box with the same number.

In relational algebra, is an operator to combine tuples from two relations that satisfy the combination condition. The particular type of whose combination condition of equality is called . Also, an operator to remove duplicated attributes from the results of by is called . Moreover, another operator to obtain all the combinations of tuples from the two relations is called .

Question 2. Draw a precedence graph to check the serializability of the following transaction schedule. Based on the graph, answer whether the transaction schedule is serializable or not. Note that T1, T2, T3, and T4 in the schedule indicate transactions, and Read and Write are operations to read and write data of the argument from and to the database, respectively.

Time	T1	T2	T3	T4
t_1	Read(X)			
t_2		Read(X)		
t_3				Read(X)
t_4			Read(X)	
t_5	Write(X)	Write(Y)		
t_6			Write(X)	Write(Y)

Question 3. Consider the following relation **Question** in the second normal form and fill in the appropriate terms in blanks (6) to (12). The underlined term indicates the primary key. Student names and affiliations are assumed to be uniquely specified by the student ID.

Question (question_no, question_content, student_ID, student_name, student_affiliation)

To express this relation in the third normal form, it is necessary to split it into the following two relations.

Question1 (question_no,)

Student ()

Based on these relations, the following SQL query extracts the unique student IDs of students who submitted questions.

SELECT FROM Question 1;

The following SQL query calculates the total number of questions from students whose affiliation is “College of Information Science and Engineering.”

SELECT FROM Question 1 WHERE (SELECT FROM Student WHERE);

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Computer Science⑨ Artificial Intelligence

This question consists of 2 pages. Answer all the questions below.

Question. For the following explanations of Artificial Intelligence (AI) from (i) to (v), choose the most suitable word or number for boxes (1) to (15) from the options shown below the explanation and answer with the symbols shown in alphabetic letters. Note that some unrelated options are included. Assume that when the same number is enclosed in the box, the answer corresponds to the same letter.

(i) In game theory, which has developed as a theory dealing with the decision-making of multiple players, equilibrium is the concept in which, if each player adopts rational behavior, the behavior that all players should adopt is naturally determined and there is no incentive to choose any other behavior. An equilibrium reached by taking behavior that yields higher rewards regardless of the opponent's behavior is called (1). The equilibrium concept that relaxes the conditions of (1) is (2). In (2), players take the best behavior given the opponent's behavior, but this can sometimes lead to an overall undesirable situation. A famous example of this is (3). Among the payoff matrices ① to ④ below, the game between players A and B that leads to (3) is number (4). In the following payoff matrices, for each cell containing numerical values, the number on the left is player A's payoff, and the number on the right is player B's payoff.

①	B: behavior1	B: behavior2
A: behavior1	2, 3	-2, 3
A: behavior1	6, 4	4, 6

②	B: behavior1	B: behavior2
A: behavior1	3, 3	8, 0
A: behavior1	0, 8	5, 5

③	B: behavior1	B: behavior2
A: behavior1	-3, 3	5, -8
A: behavior1	-5, 8	3, -3

④	B: behavior1	B: behavior2
A: behavior1	6, 6	8, 0
A: behavior1	0, 8	4, 4

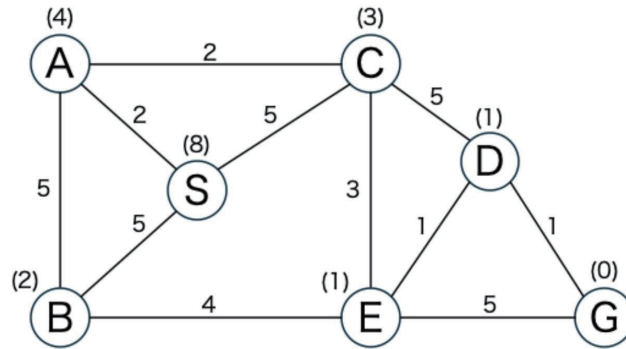
(ii) Machine learning can be classified into "supervised learning," "reinforcement learning," and "unsupervised learning." Problems addressed in supervised learning are broadly categorized into "regression problems" and "classification problems," with classification problems further divided into approaches based on "discriminative models" and (5). A Support Vector Machine (SVM) is a classifier under discriminative models capable of classifying data with complex (6). An example of a method classified under unsupervised learning is (7).

(iii) In predicate logic, a logical formula is formed by combining atomic formulas using five types of logical symbols: \neg , \wedge , \vee , \rightarrow , and \equiv . For example, a formula $P \rightarrow Q$ connected by the symbol for (8) (\rightarrow) is equivalent to (9). Once the truth values of the atomic formulas are determined, the truth value of the logical formula can be decided. When a logical formula is true regardless of the truth values of its atomic formulas, it is called (10).

(iv) In graph G_1 shown below, the numbers on edges represent transition costs, and the numbers in parentheses indicate the estimation cost for each node. The estimation is externally provided as (11) knowledge rather than being calculated from actual transition costs. (12) is an algorithm that chooses nodes with smaller estimation costs to the goal node to find the optimal path. As an

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alternative to (12), which may output incorrect results, the A* algorithm efficiently explores paths by considering both the cumulative cost to reach the current node and the estimation cost to the goal node. When finding the path from node S to G in graph G_1 using the A* algorithm, the result is (13).



(v) Dividing sentences based on natural language into meaningful units and estimating parts of speech is called (14). Further analyzing grammatical relationships is referred to as (15).

a	implication	b	search knowledge	c	equivalence	d	Bayes model
e	Pareto equilibrium	f	satisfiable	g	normal form game	h	syntactic analysis
j	morphological analysis	k	generative model	l	redundancy	m	clustering
n	tautology	o	semantic analysis	p	dominant strategy equilibrium	q	optimal search
r	nonlinearity	s	reinforcement learning	t	$P \wedge Q$	u	$\neg P \vee Q$
v	heuristic	w	Nash equilibrium	x	best-first search	y	prisoner's dilemma
z	①	A	②	B	③	D	④
E	$S \rightarrow C \rightarrow E \rightarrow G$	G	$S \rightarrow C \rightarrow D \rightarrow G$	H	$S \rightarrow A \rightarrow C \rightarrow E \rightarrow D \rightarrow G$	J	$S \rightarrow A \rightarrow C \rightarrow D \rightarrow G$

Specialized Subjects

Human Information Science

⑩ Image Processing

⑪ Artificial Intelligence

In case choosing the Human Information Science section, choose one question either ⑩ or ⑪

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Human Information Science⁽¹⁰⁾ Image Processing

This question consists of 3 pages. Answer all the questions below.

Question1.

Given a point (x, y) in the xy -coordinate system (Figure 1), its transformed coordinates (x', y') are computed through the following matrix operation. Applying this operation to all points of a geometric figure enables figure transformation.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \quad (1)$$

The transformation consists of:

- (1) A 30° counterclockwise rotation centered at the origin
- (2) A scaling transformation with magnification factor 2 along the x -axis
- (3) A translation of +3 units in the y -direction

Express the elements, a, b, \dots, f , in Equation (1) using either decimal or square root form.

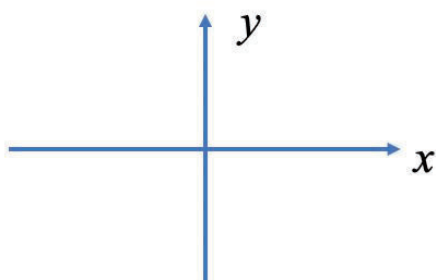


Figure 1

Question2.

For image $f(x,y)$, the intensity values at coordinates $(2,1)$, $(3,1)$, $(3,2)$, and $(2,2)$ are $f(2,1)=100$, $f(3,1)=150$, $f(3,2)=250$, and $f(2,2)=200$ respectively. Determine the value of $f(2.7, 1.2)$ using:

- (a) Nearest-neighbor interpolation
- (b) Bilinear interpolation

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Question3.

The following text describes spatial filtering. Select the correct answers for a, b, c, d, e, f, g from the [Answer Options].

- (1) The sharpening filter defined by is applied to the image in Figure 2, yielding the output value at the central pixel (target pixel).
- (2) The Laplacian filter defined by is applied to the image in Figure 2, yielding the output value at the central pixel (target pixel).
- (3) The mean filter defined by is applied to the image in Figure 2, yielding the output value at the central pixel (target pixel).
- (4) The filter that produces no change when applied to the image in Figure 2 is .

[Answer Options for a, c, e, g]

$$\text{H. } \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \text{ I. } \begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix}, \text{ J. } \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}, \text{ K. } \begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}, \text{ L. } \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

[Answer Options for b, d, f]

M. 50, N. 70.4, O. 240, P. 84.4, Q. -120, R. -140

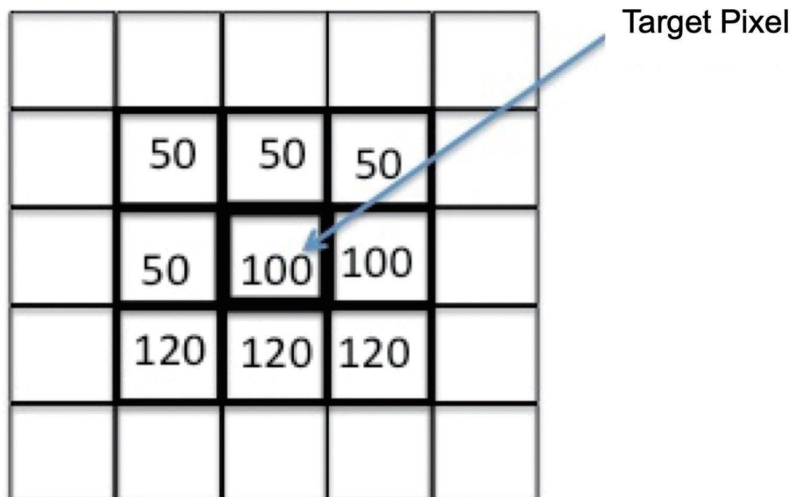


Figure 2 Input image (The central pixel (target pixel) has a value of 100.)

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Question4.

Given a grayscale image $ip[j][i]$ of size $M \times N$, the following program calculates its histogram hst . Select the correct answers for (1) and (2) from the [Answer Options]. Assume 256 intensity levels (8-bit).

```
int i, j;
int ip[N][M];
int hst[256];

for (i=0; i<256; i++)
    (1)

for (j=0; j<N; j++) {
    for (i=0; i<M; i++) {
        (2)
    }
}
```

[Answer Options]

- (a) $hst[i]=ip[j][i]$; (b) $hst[ip[j][i]]=hst[ip[j][i]]+1$; (c) $hst[i]++$; (d) $hst[i]=0$; (e) $hst[j][i]=1$;
(f) $hst[i]=ip[j][i]+1$;

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Human Information Science⑩ Artificial Intelligence

This question consists of 2 pages. Answer all the questions below.

Question 1.

There are two bags: a leather bag and a cloth bag. The leather bag is selected with a probability of $2/3$, and the cloth bag is selected with a probability of $1/3$. Each bag contains balls as described below, and once a bag is selected, every ball in that bag is equally likely to be drawn.

Furthermore, if the drawn ball is red, 1 point is awarded; if it is blue, 2 points are awarded; and if it is yellow, 3 points are awarded.

	Y₁: Red Ball	Y₂: Blue Ball	Y₃: Yellow Ball
X₁: Leather Bag	15 balls	5 balls	0 balls
X₂: Cloth Bag	15 balls	1 ball	4 balls

- A. Calculate the joint probability $P(X_1, Y_1)$ that the leather bag is selected and a red ball is drawn.
- B. Calculate the conditional probability $P(Y_3 | X_2)$ that a yellow ball is drawn given that the cloth bag is selected.
- C. Given that a blue ball was drawn, calculate the probability $P(X_1 | Y_2)$ that it came from the leather bag. Round your answer to two decimal places.
- D. Calculate the **expected value** that would be obtained. Round your answer to two decimal places.
- E. If it is known that the ball was drawn from the **leather bag**, calculate the **conditional expected value** obtained from drawing one ball. Round your answer to two decimal places.

Question 2.

- A. From the options below, choose the most appropriate description of the "Symbol Grounding Problem."
- B. From the options below, choose the most appropriate description of the "Turing Test."
- C. From the options below, choose the most appropriate description of the "Frame Problem."

<Options>

- ① How to search for decision variables that minimize or maximize an unknown objective function.
- ② How to design the physical frame that forms the skeleton of a robot operating in the real world.
- ③ How symbols within a symbolic system constructed inside a robot are connected to real-world concepts.
- ④ How to place marks (symbols) on the ground.
- ⑤ Optimization of syntactic parsing techniques for automatically translating acquired symbolic representations into another knowledge base.
- ⑥ A method for estimating latent variables that caused observed outcomes based on Bayesian inference.
- ⑦ The problem that attempting to handle all real-world objects leads to enormous computation time and makes real-time processing impossible.
- ⑧ A method for constructing human-like intelligence by learning from experience through a bottom-up approach including the body.
- ⑨ Learning based on retrospective evaluations including time delays in actions, similar to how humans learn through trial and error.
- ⑩ Determining whether a machine has intelligence by judging from its responses through a monitor whether it is human or machine.

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Question 3.

For each blank below, choose the most appropriate term from the given options.

In multi-stage decision problems, when there are always a finite number of choices, the number of possible solutions increases in a(n) [A].

To suppress this, [B], an algorithm that reduces computational complexity by representing each evaluation value as a sum of bivariate functions over state pairs, is used.

In [B], the search for solutions is made more efficient by the evaluation value at each state using [C].

On the other hand, when state transitions are probabilistic, reinforcement learning may be used.

In reinforcement learning, the environment's state transitions are modeled as a [D], and the policy is learned so as to maximize the [E].

<Options>

- ① Exponential order
- ② Logarithmic order
- ③ Polynomial order
- ④ Linear order
- ⑤ Dynamic programming
- ⑥ Linear programming
- ⑦ Ward's method
- ⑧ Greedy method
- ⑨ Discounted cumulative reward
- ⑩ Knowledge graph
- ⑪ Finite automaton
- ⑫ State transition diagram
- ⑬ Markov Decision Process
- ⑭ Memoization
- ⑮ Edit distance
- ⑯ Prediction error
- ⑰ Deletion
- ⑱ Clustering
- ⑲ Accuracy of training data
- ⑳ Learning rate

February 2026 Admissions

AY2026 Examination Questions for the Graduate School of
Information Science and Engineering, Ritsumeikan University
(Master's Program)

**Major in Information Science and Engineering
Information Science and Engineering Course**

【How to answer questions】

Please follow the instructions below and answer the questions.

- 1) Choose two questions from question ①~③ for Common Subjects.
 - 2) Choose either the Computer Science section or the Human Information Science section for Specialized Subjects.
 - In case choosing the Computer Science section, answer three questions from question ④~⑨.
 - In case choosing the Human Information Science section, choose one question either ⑩ or ⑪.
- *There will be two blank answer sheets in case choosing the Human Information Science section.

Examination Subjects and Questions		Allocation of Points		Remarks	
Common Subjects	① Linear Algebra	100 points	Total 200 points	Choose 2 out of the 3 questions	
	② Probability and statistics	100 points			
	③ Data structure and algorithms	100 points			
Specialized Subjects	Computer Science	④ Computer Architecture	-	Total 100 points	Choose 3 out of the 6 questions
		⑤ Operating System	-		
		⑥ Software Engineering	-		
		⑦ Computer Networks	-		
		⑧ Databases	-		
		⑨ Artificial Intelligence	-		
	Human Information Science	⑩ Image processing	100 points	Total 100 points	Choose 1 out of the 2 questions
		⑪ Artificial Intelligence	100 points		

【Examination time】

9:30-11:30 (120minutes)

※Leaving the examination venue is not allowed during the examination time.

※In case you feel sick or need to go to the bathroom, let examination supervisors know by raising your hand.

【Notes】

- (1) Use one answer sheet for one question.
- (2) Fill out your examination number and name for all the answer sheets. Also, make sure to fill out all the other necessary sections such as the questions number column.
- (3) Do not remove the staple of your answer sheets.
- (4) Answer sheets with no names will be invalid and the score will be 0 points.
- (5) Do not take the question sheets and answer sheets with you after the examination.

Common Subjects

- ① Linear Algebra
- ② Probability and Statistics
- ③ Data Structure and Algorithms

Choose two questions from the above.

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Common Subjects① Linear Algebra

Answer all the questions below.

Question1. Given four points $A(1, -1, 2)$, $B(3, 0, 5)$, $C(-1, 1, 1)$ and $D(2, 2, 0)$, answer the following questions.

- (1) Find the scalar product (dot product) $\overrightarrow{AB} \cdot \overrightarrow{AC}$.
- (2) Find the value of $\cos \theta$, where θ ($0 \leq \theta \leq \pi$) is the angle between vector \overrightarrow{AB} and \overrightarrow{AC} .
- (3) Find the orthogonal projection (vector projection) \vec{p} of the vector \overrightarrow{AD} onto the direction of the vector \overrightarrow{AB} .
- (4) Determine whether the set of vectors $\{\overrightarrow{AB}, \overrightarrow{AC}, \overrightarrow{AD}\}$ is linearly independent or linearly dependent. State your reason concisely.

Question2. Let the matrices A and B be defined as follows:

$$A = \begin{pmatrix} 1 & 0 \\ 4 & -1 \end{pmatrix}, \quad B = \begin{pmatrix} 1 & -1 \\ 2 & 4 \end{pmatrix}$$

- (1) Find the n -th power of matrix A , A^n , where n is a positive integer.
- (2) Find the eigenvalues λ of matrix B and their corresponding eigenvectors.
- (3) Find the invertible matrix P and the corresponding diagonal matrix D that diagonalizes matrix B .
Assume $B = PDP^{-1}$.

End of questions.

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Common Subjects② Probability and Statistics

This question consists of a single page.

Answer all the questions below. Show the calculation processes.

Question 1.

Suppose you roll a fair four-sided die, with the digits from 1 to 4, each occurring with equal probabilities. Let the result be $X \in \{1, 2, 3, 4\}$.

- (1) Obtain the expected value $E[X]$ of X .
- (2) Obtain the expected value $E[X^2]$ of X^2 .
- (3) Obtain the variance $V[X]$ of X .
- (4) Obtain the expected value $E[2X]$ and the variance $V[2X]$ of $2X$.
- (5) Suppose you roll the above die twice, and let the first and the second results be X_1 and X_2 , respectively. Then obtain the expected value $E[X_1 + X_2]$ and the variance $V[X_1 + X_2]$ of the sum $X_1 + X_2$. To obtain the solution, first prove that $E[X_1 + X_2] = E[X_1] + E[X_2]$, and $V[X_1 + X_2] = V[X_1] + V[X_2]$ from the independency of X_1 and X_2 , then obtain each value.

Question 2.

Suppose you take an exam which is a set of multiple-choice questions. For each question, you must choose one correct answer. As you take it without studying, you make the choice randomly for all questions.

- (1) When there are four questions, each of which is a two-choice question, what is the probability distribution $P_1(X_1)$ of the number of the correct answers X_1 ? Show the formula of the probability mass function $P_1(X_1 = k)$, ($k = 0, 1, \dots, 4$).
- (2) Obtain the expected value m_1 of $P_1(X_1)$ in the previous question (1), and the probability that all answers are incorrect $P_1(X_1 = 0)$.
- (3) When there are 2^4 questions, each of which is 2^3 -choice question, what is the probability distribution $P_3(X_3)$ of the number of the correct answers X_3 ? Show the formula of the probability mass function $P_3(X_3 = k)$. In addition, obtain the expected value m_3 of $P_3(X_3)$, and the probability that all answers are incorrect $P_3(X_3 = 0)$. The solution may be expressed in power notation.
- (4) When there are 2^{n+1} questions, each of which is 2^n -choice question (n is a natural number), what is the probability distribution $P_n(X_n)$ of the number of the correct answers X_n ? Show the formula of the probability mass function $P_n(X_n = k)$. In addition, obtain the expected value m_n of $P_n(X_n)$, and the probability that all answers are incorrect $P_n(X_n = 0)$. The solutions must contain n , and may be expressed in power notation.
- (5) Consider the limit as n approaches infinity. What is the probability distribution $P_\infty(X_\infty)$ of the number of the correct answers X_∞ ? Show the formula of the probability mass function $P_\infty(X_\infty = k)$. In addition, obtain the expected value m_∞ of $P_\infty(X_\infty)$, and the probability that all answers are incorrect $P_\infty(X_\infty = 0)$. The solution may be expressed in terms of Napier's constant e .

End of questions.

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Common Subjects③ Data Structure and Algorithms

This question consists of 2 pages.

Answer all the questions below.

Question 1. Fill in the blanks [①] through [⑪] in the following passages with the appropriate terms or expressions. The same number corresponds to the same word throughout the passage (1) to (2), so read the entire text carefully and insert the correct terms or expressions.

- (1) A data structure refers to the way in which multiple pieces of data are organized and stored in a computer, with concrete examples including arrays and linked lists. An algorithm is a method or procedure for manipulating data within a data structure, such as [①] and [②]. Even algorithms that produce the same result can differ, and they are usually evaluated based on the criteria of [③] or [④]. [③] refers to the computation time required to execute the algorithm, while [④] refers to the memory space used during execution. In general, when we speak of computational complexity, we mean [③]. When comparing algorithm efficiency, we use asymptotic analysis with order notation to evaluate complexity for sufficiently large data size n . For example, the process of finding data with a specific key from a table containing n entries is called [①], and includes methods such as linear search and binary search. The computational complexity of the former is [⑤], while that of the latter is [⑥].
- (2) [②] refers to the process of rearranging data according to a certain criterion, and can be classified into those that use comparisons and those that do not. Among those that use comparisons, simple [②] algorithms such as [⑦] and [⑧] have a computational complexity of $O(n^2)$ in both average and worst cases, but both are known as stable [②] algorithms. An improved and faster version of [⑦] is Shell sort. Faster algorithms such as [⑨] and [⑩] have a computational complexity of $O(n \log n)$ in both average and worst cases. [⑨] is stable, whereas [⑩] is an unstable [②] algorithm. Algorithms that do not use comparisons include [⑪]. The principle of [⑪] is to divide the key into several subkeys and then perform stable [②] operations on the subkeys in order from the least significant to the most significant.

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Question 2. Recursive call refers to the act of invoking a procedure from within itself. Answer the following questions related to recursive calls.

- (1) The sequence defined by the recurrence relation

$$\begin{cases} f(0) = f(1) = 1, \\ f(n) = f(n-1) + f(n-2) \quad (n \geq 2) \end{cases}$$

is called the Fibonacci sequence, consisting of $f(0), f(1), f(2), \dots$. Write pseudocode for a function `int Fibonacci_rec(int n)` that returns the n -th value $f(n)$ of the Fibonacci sequence using recursive calls.

- (2) It is known that computing the Fibonacci sequence using recursive calls results in an order of computational complexity that grows exponentially with n , making it highly inefficient. Therefore, write pseudocode for a function `int Fibonacci(int n)` that computes $f(0), f(1), f(2), \dots$ sequentially without using recursion and finally returns $f(n)$. Also, state the order of computational complexity for this process.

- (3) The Tower of Hanoi problem is as follows:

There are three rods, A, B, and C, and n disks of different sizes with holes in the center. Initially, all disks are stacked on rod A in order of size, with the largest at the bottom (see Figure 1). Starting from this initial state, we want to move all disks to rod C, subject to the following three conditions:

- (i) Only one disk can be moved at a time.
- (ii) A larger disk cannot be placed on top of a smaller disk.
- (iii) Any disk removed from a rod must be placed on one of the rods A, B, or C.

Now, define the procedure

`Hanoi(n, A, B, C)`

as the process of moving n disks from rod A to rod C using rod B as an auxiliary. Write pseudocode for this procedure using recursive calls. Assume that the code to move one disk from rod x to rod y is written as

`MoveOneDisk(x, y)`.

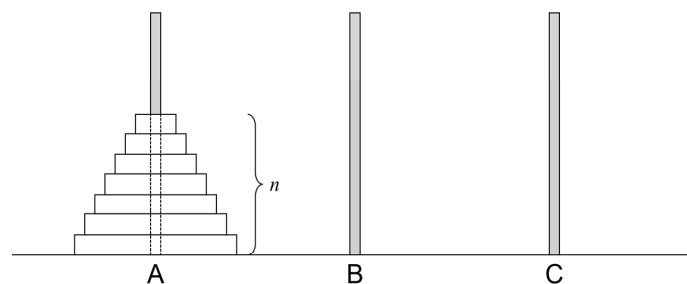


Figure 1. Initial state of the Tower of Hanoi

Specialized Subjects

Computer Science

- ④ Computer Architecture
- ⑤ Operating System
- ⑥ Software Engineering
- ⑦ Computer Networks
- ⑧ Databases
- ⑨ Artificial Intelligence

In case choosing the Computer Science section, answer three questions from question ④～⑨

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Computer Science④ Computer Architecture

This question consists of 2 pages.

Consider the following MIPS assembly program. Answer **Questions 1, 2, and 3**.

In the program below, everything after # on each line is a comment describing what that instruction does.

The numbers in parentheses at the beginning of each line are line numbers used only for answering the questions and are not part of the actual program.

```
(1)   add  $8,$0,$0      # Store $0 + $0 into $8 (since $0 is always 0, $8 becomes 0).
(2)   lui  $9,0xC000    # Load 0xC000 into the upper 16 bits of $9 and set the lower 16 bits to 0.
(3)LOOP: lw  $10,0($9)  # Load the memory contents at address in $9 into $10.
(4)   beq  $10,$0,HALT  # If $10 is 0, branch to HALT.
(5)   slt  $11,$8,$10   # If $8 < $10 then $11 = 1, otherwise $11 = 0.
(6)   beq  $11,$0,L     # If $11 is 0, branch to L.
(7)   add  $8,$0,$10    # Store the value of $10 into $8.
(8)L:  addi $9,$9,4      # Increase the value of $9 by 4.
(9)   j    LOOP        # Unconditional jump to LOOP.
(10)HALT:j   HALT      # Jump to HALT (effectively halts the program).
```

Question 1

The behavior of the above program is described by the following sentence, which contains blanks ① and ②.

Fill in the blanks with appropriate expressions.

“This program sequentially reads 4-byte data as integers from memory starting at address ① until it reads a value of 0. Among the values read, it stores ② into register \$8.”

Note: Answer blank ① as an 8-digit hexadecimal address (e.g., 0x1234ABCD).

Question 2

Now consider executing the above program on a 5-stage pipeline processor with stages IF, ID, EX, MEM, and WB.

Assume that the lw instruction reads data from memory in the MEM stage, and that each instruction performs its operation using register file values and produces its result in the EX stage.

Answer all of the following questions (a), (b), and (c).

(a) List all pairs of instructions (producer and consumer) that cause data hazards which can be resolved by forwarding. Answer using the line numbers of the producer and the consumer instructions.

(b) The above program also has a data hazard that cannot be resolved by forwarding. Therefore, if the program is executed on the pipeline “as is,” the result of the pipelined execution will differ from that of a sequential execution. To obtain the same result as sequential execution on the pipelined processor, it is sufficient to insert a single nop instruction. After which instruction should this nop be inserted? Answer with the line number of that instruction.

(c) In (b), you added one nop instruction. However, even without adding any new instructions, it is possible to obtain the same result in \$8 with sequential execution by only reordering the instructions in the above program. Explain how you would reorder the instructions to achieve this.

Question 3

Consider a pipeline design in which no branch prediction is used for the execution of the beq instruction, and both the evaluation of the branch condition and the determination of the branch target address for a beq instruction are performed at the very end of the EX stage. Also assume that no delayed branching is used. Answer all of the following questions (a), (b), and (c).

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(a) At the moment when it is determined in the EX stage that the branch is taken, how many of the instructions that follow beq that are already in the pipeline must be replaced with instructions that perform no operation (i.e., become effectively null)?

Answer with the number of instructions.

(b) What is the name of the operation described in (a), where instructions already in the pipeline that should not be executed are invalidated?

(c) What is the situation called in which the instruction that should be executed after a branch cannot be determined immediately, and as a result the pipeline execution is affected?

End of questions.

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Computer Science(5) Operating System

Answer all the questions below.

Question 1.

Answer the following questions about techniques for safely using shared resources with mutual exclusion.

- (1) Explain what operation the Test-and-Set instruction (hereafter abbreviated as TS instruction) performs.
- (2) The TS instruction is not a privileged instruction, so it can be used even in user mode. Describe the advantage of using the TS instruction for mutual exclusion within a user process without using system calls for semaphores.
- (3) When mutual exclusion is performed using the TS instruction as in (2), explain how it is used at the machine-language level. Also explain what a spinlock is in that context, and explain situations in which the spinlock becomes a disadvantage.
- (4) Describe an implementation that avoids spinlocks while maintaining the advantages of the TS instruction to efficiently achieve mutual exclusion for shared resources. Include in your explanation what happens both when a process fails to acquire the shared resource and when it successfully acquires and releases the resource, along with why this approach is efficient.

End of questions.

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Computer Science⑥ Software Engineering

Answer all the questions below.

- (1) Explain the term “rework” in software development.
- (2) Using the terms “development cost” and “quality,” explain the effects of software reuse, including the reasons behind those effects.
- (3) In integration testing, explain the advantages of “top-down testing” and “bottom-up testing”, respectively.
- (4) Consider testing the validity of an input value in a web form. This form prompts the user to input a single integer value representing the user's age and checks whether the input is under 20. The input conditions for this test are as follows:
 - Valid equivalence class: values 0 to 19
 - Invalid equivalence class: values 20 and above

Based on these conditions, describe the minimum set of input values required for test cases derived from equivalence partitioning and, separately, the minimum set of input values required for test cases derived from boundary value analysis. The input is constrained to integer values of 0 or greater, and any inputs other than positive integers (including zero) are not considered.

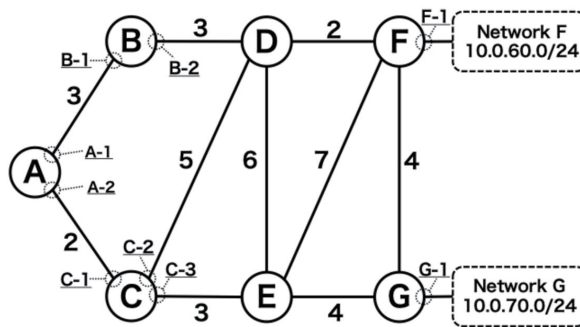
End of questions.

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Computer Science⑦ Computer Networks

This question consists of 2 pages. Answer all the questions below.

Question1. For the network topology shown below, node A wishes to compute the shortest path (minimum-cost path) to each node (B–G) and construct its routing table. In the figure, the letters inside circles denote identifiers of nodes, and the lines between nodes represent links (connections). The numerical value shown beside each link indicates the cost associated with that link. The underlined letters at the connection points between nodes and links represent the network interfaces of each node, and the table below shows the IP addresses assigned to several of these interfaces. Networks F and G are connected to interfaces F-1 and G-1, respectively.



Interface	IP address
A-1	10.0.10.1/24
A-2	10.0.20.1/24
B-1	10.0.10.2/24
B-2	10.0.30.1/24
C-1	10.0.20.2/24
C-2	10.0.40.1/24
C-3	10.0.50.1/24
F-1	10.0.60.1/24
G-1	10.0.70.1/24

- (1) Apply Dijkstra's algorithm to the network shown above, and for each step, answer the node whose shortest path from node A has been determined, the sequence of nodes through which a packet should pass to reach that node, and the distance (total cost) from node A to that node. Fill these values in the **Node**, **Route**, and **Distance** columns, respectively, and complete the table on the right. The table already shows the results for Step 1 (for node A) and Step 2 (for node C), for which the shortest paths have been determined. As indicated in the table, the **Route** column should list all nodes that the packet traverses, including the source and destination, connected by hyphens (-). For example, if a packet sent from node A reaches node D via node C, the entry should be written as A-C-D. **Write the completed table including your final answers on the answer sheet provided.**

Step	Node	Route	Distance
1	A	A-A	0
2	C	A-C	2
3			
4			
5			
6			
7			

- (2) After determining the shortest paths to all nodes using Dijkstra's algorithm, node A constructs its routing table. The table below shows an excerpt of the routing table configured on node A. Complete the routing table by filling in the IP addresses of the Gateways for the cases where the destinations are networks F and G. All networks in the network topology use a subnet mask of /24, and only the IP address should be written in the **Gateway** column. **Write the completed table including your final answers on the answer sheet provided.**

Destination	Gateway
10.0.60.0/24	
10.0.70.0/24	

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Question2. For each of the descriptions (1)-(5) related to computer networks, answer the most appropriate terms for the boxed items (a)-(j). If choices ①-④ are provided with the boxed item, answer the symbol of the correct choice. If no choices are shown, answer an appropriate term. Note that the boxed items with identical letters (e.g., (a), (c)) should be filled with the same term.

- (1) Among the seven layers of the OSI reference model, the layer that provides functions related to data transfer between adjacent nodes (computers) directly connected by a communication medium is the

(a) ① Application ② Data Link ③ Transport ④ Network

layer. Among the functions provided by the (a) layer, the function in which the sending node adds special bit patterns to mark the beginning and end of a frame, allowing the receiving node to identify boundaries of each frame within the received bitstream is called

(b) ① Error Control ② Synchronous Control ③ Congestion Control ④ Flow Control .

- (2) The IETF, which promotes the standardization of Internet technologies, publishes technical specifications as documents assigned serial numbers called

(c) ① RFC ② RSVP ③ RTC ④ RTP .

For example, (c) 793 describes the specifications of TCP including the procedure for the (d) handshake required to establish a connection prior to data communication between hosts.

- (3) In DNS servers, the

(e) ① A ② AAAA ③ NS ④ SOA

record stores the IPv6 (Internet Protocol version 6) address associated with a domain name while the (f) record stores the mail servers responsible for receiving email for that domain.

- (4) Among binary line-coding schemes that use two signal levels (e.g., two voltage levels or on/off light pulses) for transmitting digital signals,

(g) ① MLT-3 ② NRZ ③ NRZI ④ RZ

inverts the signal level when transmitting a data of 1 and leaves the signal level unchanged when transmitting a data of 0. In addition, the encoding method that selects 16 bit patterns from all possible 5-bit sequences, specifically those sequences that do not contain three or more consecutive zeros, and maps them to all 16 possible 4-bit patterns is called (h) encoding.

- (5) A computer is assigned the IPv4 address 10.10.22.123 (in dotted decimal notation) and the subnet mask 255.255.255.224. In this IP network, the network address is

(i) ① 10.10.22.0 ② 10.10.22.64 ③ 10.10.22.96 ④ 10.10.22.112

and the maximum number of computers that can be connected to this network is (j) .

End of questions.

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Computer Science⑧ Databases

This question consists of 2 pages. Answer all the questions below.

Question 1.

Choose the appropriate term from the **Options** and fill in the blanks **A** to **C** in the following description concerning normalization in relational databases.

Consider the relation “Order” defined as follows:

Order(orderID, customerName, customerAddress, productPrice)

There exists **A** such that orderID uniquely determines customerName and productPrice, and customerName uniquely determines customerAddress. In this case, this relation satisfies **B** normal form, but does not satisfy **C** normal form.

In addition, normalize the relation “Order” into **C** normal form and write the resulting relations. You may choose any names for the normalized relations. Underline the key attributes of each relation.

Options:

- a. consistency b. primary key c. candidate key d. inconsistency e. functional dependency f. serializability
g. complete h. incomplete i. relation j. first k. second l. third

Question 2.

Given the following three relations (tables), choose the appropriate terms from the **Options** and fill in the blanks **D** to **H** in the SQL statement that retrieves all course names taken by students in department number 5. The same term should be used for blanks marked with the same letter.

Relations (tables):

Student(studentID, studentName, departmentID)

Enrollment(studentID, courseID, score)

Course(courseID, courseName)

SQL Statement:

```
SELECT courseName
FROM D
WHERE E IN (
    SELECT E
    FROM F
    WHERE G IN (
        SELECT G
        FROM H
        WHERE departmentID = 5
    )
)
```

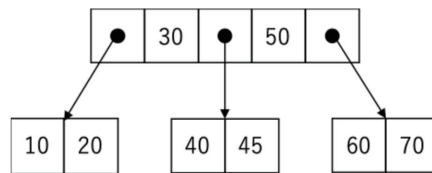
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Options:

a. Student b. Enrollment c. Course d. studentID e. studentName f. departmentID
g. courseID h. score i. courseName j. * k. DISTINCT l. HAVING

Question 3.

Insert the key value 28 into the B-tree shown in the figure below (in which each node can contain at most two keys), and draw the resulting B-tree using the same notation as in the figure.



End of questions.

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⑨ Artificial Intelligence

This question consists of 2 pages.

Answer all the questions below.

Question : For the following explanations of Artificial Intelligence (AI) from (i) to (v), choose the most suitable term or number for the boxes (1) to (15) from the options shown below each explanation and answer with the symbols shown in alphabetic letters. Note that some unrelated options are included. Assume that the same term or number is enclosed in each box with the same number.

(i) The Naive Bayes filter is a document classification method that assumes that word generation follows the assumption of , and applies Bayes' theorem to categorize documents. Given a set of words $\{w_1, w_2, \dots, w_n\} \in W$, the Naive Bayes classifier computes the probability $P(z_i|w_1, w_2, \dots, w_n)$ that the document belongs to class z_i , based on the following formula.

$$P(z_i|w_1, w_2, \dots, w_n) = \frac{\text{input (2)}}{P(w_1, w_2, \dots, w_n)}$$

Suppose we use a Naive Bayes filter to determine whether an incoming email is spam or legitimate. The probabilities that each word w_1, w_2, w_3 appears in spam emails and in legitimate emails are given in the following table. If spam emails arrive with prior probability 0.3, then the probability that an email containing words w_1 and w_2 , but not w_3 , is spam is approximately .

	w_1	w_2	w_3
$P(w_i \text{spam email})$	0.5	0.7	0.2
$P(w_i \text{legitimate email})$	0.6	0.2	0.5

【Options for (i)】

a	topic dependence	b	$P(z_i) \cdot \prod_{w_i \in W} P(z_i w_i)$	c	$P(z_i) \cdot \prod_{w_i \in W} P(w_i z_i)$	d	$\prod_{w_i \in W} P(w_i z_i)$
e	conditional independence	f	0.084	g	0.333	h	0.667

(ii) Consider search problems. Let $g(u)$ denote the total cost along the optimal path from the start node S to node u , and let $h(u)$ denote the total cost along the optimal path from node u to the goal node G . The symbol $\hat{}$ represents an estimated value; for example, $\hat{h}(u)$ is an estimate of $h(u)$, and in this case $\hat{h}(u)$ serves as the heuristic estimate for node u .

In optimal search (Dijkstra algorithm) and the A^* algorithm, nodes are expanded in increasing order of their evaluation values while updating those values. In optimal search, when a node u is expanded, its evaluation value equals , and the optimality of the obtained solution is guaranteed. In contrast, the A^* algorithm guarantees optimality only when the condition holds for every node u . Furthermore, when the condition holds for every node u , the behavior of A^* algorithm becomes identical to that of optimal search.

【Options for (ii)】

a	$g(u)$	b	$\hat{g}(u)$	c	$\hat{g}(u) + \hat{h}(u)$	d	$\hat{g}(u) = h(u)$
e	$\hat{h}(u) \leq h(u)$	f	$h(u) \leq \hat{h}(u)$	g	$\hat{h}(u) = 0$	h	$\hat{g}(u) = 0$

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(iii) The k-means method is a deterministic clustering algorithm that assigns each data point to a cluster based on the to the cluster representatives. In contrast, clustering with a mixture distribution model assumes that data are generated from a mixture of multiple probability distributions, and computes the that each data point belongs to a particular component. The , which is used for inference in Gaussian mixture models, repeatedly performs a step that updates parameters such as mixture weights, means, and variances, and a step that assigns clusters by computing these .

【Options for (iii)】

a	posterior probability	b	generation probability	c	distance	d	prior probability
e	LDA	f	variance	g	EM algorithm	h	autoencoder

(iv) Reinforcement learning is a framework in which an agent learns an optimal policy through trial and error within an environment. At each step, the agent receives a state from the environment, selects an action, and obtains a as a result of that action. A is often applied to compute the present value of the that will be obtained in the future. In Q-learning, the action-value function is updated using the , which is the difference between the actual received and the predicted value.

【Options for (iv)】

a	squared error	b	training data	c	learning rate	d	Q-value
e	TD error	f	reward	g	policy	h	discount factor

(v) One of the most fundamental document representations in natural language processing is the , in which each document is expressed as a high-dimensional vector whose components correspond directly to word occurrence frequencies. However, the ignores word order. In contrast, features use sequences of n adjacent words or characters as units and includes them as features. Furthermore, is a pre-trained language model that captures how the meaning of a word changes depending on its surrounding context within a sentence.

【Options for (v)】

a	n-gram	b	BERT	c	Bag-of-Words representation	d	word2vec
e	one-hot vector	f	LSTM	g	TF-IDF	h	skip-gram

End of questions.

Specialized Subjects

Human Information Science

⑩ Image Processing

⑪ Artificial Intelligence

In case choosing the Human Information Science section, choose one question either ⑩ or ⑪

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Human Information Science[®] Image Processing

This question consists of 2 pages.

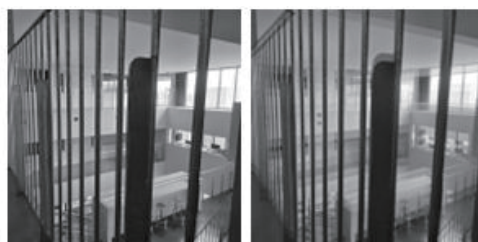
Answer all the questions below.

Question 1. The pixel intensity values at the coordinates $(0, 0)$, $(30, 0)$, $(0, 30)$, and $(30, 30)$ are 15, 90, 60, and 180, respectively. Find the pixel intensity value at the coordinate $(20, 10)$ using both the nearest-neighbor method and the bilinear interpolation method.

Question 2. The degradation process of an input image $f(x, y)$ into an output image $g(x, y)$ can be expressed using a point spread function $k(x, y)$. Specifically, by using the convolution operator \otimes , it is modeled as $g(x, y) = (f \otimes k)(x, y)$.

Please note that in the power spectrum of the Fourier transform of an image, the center corresponds to the DC component, and larger values are represented in white. Also, the images are not to scale.

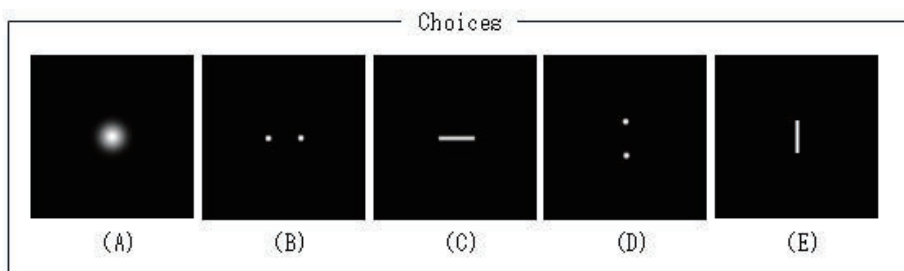
- (1) The input image and the output image are as shown in Figure 1. Select the most appropriate point spread function from the given choices to represent this degradation process.



Input image

Output image

Figure 1

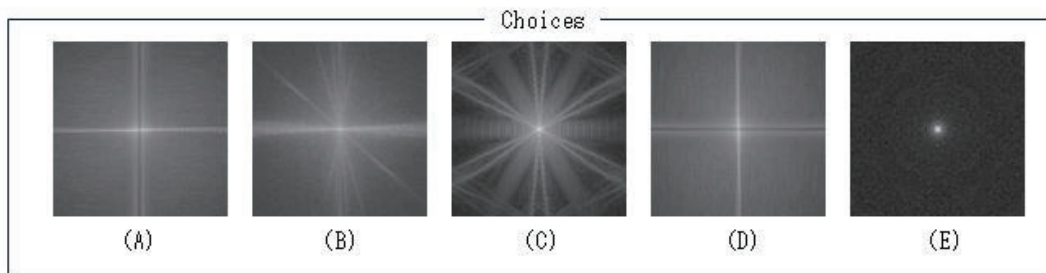


- (2) The input image is as shown in Figure 2. Select the most appropriate power spectrum representation of its Fourier transform from the given choices.



Figure 2: Input image

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(3) The power spectrum of an input image and a given point spread function Fourier-transformed are as shown in Figure 3. When the image is degraded by this point spread function, select the most appropriate power spectrum of the output image from the given choices.

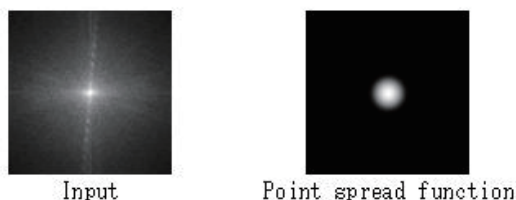
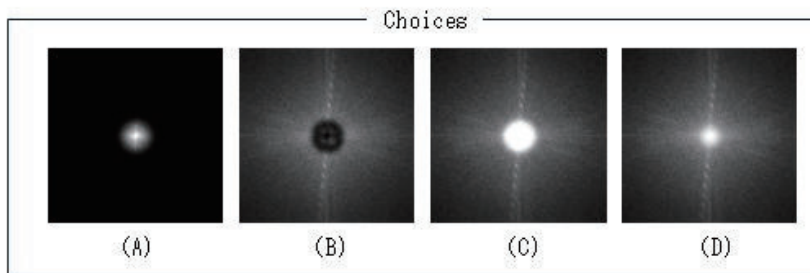


Figure 3



Question 3. On the two-dimensional image plane (u, v) , coordinate transformation can be expressed using a homogeneous coordinate system as follows:

$$\begin{pmatrix} y_u \\ y_v \\ 1 \end{pmatrix} = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix} \begin{pmatrix} x_u \\ x_v \\ 1 \end{pmatrix},$$

where (x_u, x_v) and (y_u, y_v) are the coordinates before and after transformation, and a through i are the matrix elements.

- (1) Give the matrix elements when performing a coordinate transformation consisting of a 45° rotation about the origin, followed by translation by 10 units along the u -axis and 3 units along the v -axis.
- (2) Give the matrix elements when performing a coordinate transformation consisting of a 45° rotation about the point $(10, 3)$.
- (3) Suppose the normal vector at the point (x_u, x_v) is $(\frac{1}{2}, \frac{\sqrt{3}}{2})$. Find the value of the normal vector at the transformed point after applying the same coordinate transformation as in (1).

End of questions.

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Human Information Science① Artificial Intelligence

This question consists of 2 pages.

Answer all the questions below.

Question 1.

A search is conducted for a path on the weighted graph in Figure 1. In the Figure 1, \square represents each node, the number attached to the edge between nodes represent the cost of moving along that edge, and the numbers in parentheses attached to the nodes represent the predicted evaluation value of that node. Answer the following questions.

- (1) Show the optimal path and optimal cost obtained when performing an optimal search for the weighted graph. Show the calculation process.
- (2) Find the path obtained by the A* algorithm. However, indicate the search order of each node in the search process and the nodes and evaluation values included in the open list and closed list in each search order as "node (evaluation value)" (e.g., A(2), B(4)). If any numbers in the open list are the same, they should be placed in alphabetical order.
- (3) Explain the conditions necessary to ensure that the solution of the A* algorithm matches the solution of the optimal search.

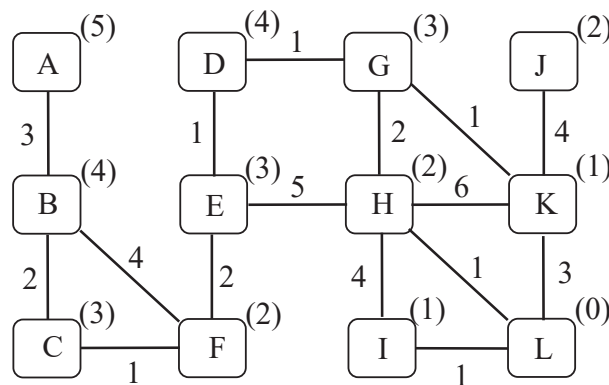


Figure 1. Cost-added graph

Question 2.

In a certain email filtering system, the following two features X_1 and X_2 are used to determine whether an email is spam (S) or not (N).

X_1 : The email contains the word "free" (if yes, $X_1 = 1$; if no, $X_1 = 0$)

X_2 : The email contains the word "limited" (if yes, $X_2 = 1$; if no, $X_2 = 0$)

The output distribution of these two words is shown in Table 1. Let the random variable C be $C = 1$ if it is spam mail and $C = 0$ if it is normal email. Then, the generation of each word is assumed to be conditionally independent given C . Answer the following questions.

- (1) Express $P(C|X_1, X_2)$ using $P(X_1|C)$, $P(X_2|C)$, $P(C)$, and $P(X_1, X_2)$.
- (2) If the percentage of legitimate emails among all received emails is 80%, calculate the probability that an email containing "free" and not containing "limited" is spam. Explain your derivation process.

Table 1: Output distribution for each word "Free" and "Limited"

	"Free"	"Limited"
Spam email	0.70	0.10
Normal email	0.60	0.20

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Question 3.

Answer the following questions.

Choose the most appropriate word or phrase from the choices below to fill in the blank in the following sentence about reinforcement learning, and write the most appropriate number.

Humans learn through [(1)] in their studies and sports. They try out a certain action, see whether the result was good or bad, evaluate their action, and gradually improve their way of doing things. In the field of psychology, the formation of behavior through [(2)] obtained as a result of consequences as satisfying or discomfoting is called [(3)]. Reinforcement learning is formulated based on [(4)]. As variables, state $s_t \in S$ is observed at time t , and action $a_t \in A$ is taken. At this time, a transition to state $s_{t+1} \in S$ is made based on [(5)] $P(s_{t+1}|s_t, a_t)$. In addition, it is assumed that at each time, $s_{t+1} \in S$, which corresponds to the payoff, is obtained as $r_{n+1} = r(s_t, a_t)$ [(2)].

[Choices] 1. Thinking 2. Markov process 3. Markov decision process 4. Policy 5. State value function 6. State transition probability 7. Trial and error 8. Internal model 9. Action value 10. Discounted cumulative reward 11. Reward 12. Operant conditioning 13. Skinner box 14. TD error 15. Greedy method

End of questions.