

# Ritsumeikan University Graduate School AY2021 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 2022 Enrollment)	P.21～	
International Student Admissions (English-based Program)		July (September 2021 Enrollment)		
		August		
		December		
In-University Advancement Admissions (English-based Program)		July (September 2021 Enrollment)		
		July		
		February (September 2022 Enrollment)		
Accelerated Learners (Grade Skippers) (English-based Program)		February	P.21～	

# Ritsumeikan University Graduate School

## AY2021 Entrance Examination

# Doctoral Program

### Graduate School of Information Science and Engineering

#### Advanced Information Science and Engineering Major

Admissions	Examination	Major Subjects (Common Subjects・Specialized Subjects)	
		Page	Notes
Regular Admissions (English-based Program)	July (September 2021 Enrollment)		
	August		
	February		
	February (September 2022 Enrollment)		
International Student Admissions (English-based Program)	July (September 2021 Enrollment)		
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	July		
	February (September 2022 Enrollment)		

August 2021 Admissions

**AY2022 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.

Choose two questions from the common subjects and choose either the Computer Science section or the Human Information Science section.

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.

Common Subjects	① Linear Algebra ② Probability and Statistics ③ Data Structure and Algorithms	
Specialized Subjects	Computer Science	④ Computer Architecture ⑤ Operating System ⑥ Software Engineering ⑦ Computer Networks ⑧ Databases ⑨ Artificial Intelligence
	Human Information Science	⑩ Image Processing ⑪ Artificial Intelligence

**【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. 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.

Question 1. Let  $A = \begin{bmatrix} 2 & 0 & 1 \\ -2 & 3 & 4 \\ -5 & 5 & 6 \end{bmatrix}$ .

- ( 1 ) Find the inverse of  $A$ .  
( 2 ) Solve the following simultaneous equations using the result of ( 1 ) .

$$\begin{cases} 4x + 2z = 8 \\ -4x + 6y + 8z = 6 \\ -10x + 10y + 12z = 4 \end{cases}$$

Question 2. Let  $A = \begin{bmatrix} 1 & 4 \\ 2 & 3 \end{bmatrix}$ .

- ( 1 ) Find the eigenvalues and the eigenvectors of  $A$ .  
( 2 ) Find the diagonalized result of  $A$ .  
( 3 ) Solve  $A^{50}$ .

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**Common Subjects ② Probability and Statistics**

Answer all the questions below with derivation.

Question 1. Find positive constant  $k$  of the following joint probability density function  $f(x,y)$  for two continuous random variables  $X$  and  $Y$ . Then, obtain each marginal probability density function for  $X$  and  $Y$ . Are  $X$  and  $Y$  independent? Justify your answer.

$$(1) f(x,y) = \begin{cases} k, & (0 < x < 1, 0 < y < 1), \\ 0, & (\text{Otherwise}) \end{cases}$$

$$(2) f(x,y) = \begin{cases} k \cdot (1-x)(1-y), & (0 < x < 1, 0 < y < 1), \\ 0, & (\text{Otherwise}) \end{cases}$$

$$(3) f(x,y) = \begin{cases} k, & (x > 0, y > 0, x+y \leq 1), \\ 0, & (\text{Otherwise}) \end{cases}$$

$$(4) f(x,y) = \begin{cases} k \cdot (1-x-y), & (x > 0, y > 0, x+y \leq 1), \\ 0, & (\text{Otherwise}) \end{cases}$$

$$(5) f(x,y) = \begin{cases} k \cdot \exp(-x-y), & (x > 0, y > 0), \\ 0, & (\text{Otherwise}) \end{cases}$$

Question 2. Suppose  $X$  and  $Y$  are two discrete random variables that take values from  $\{1,2,3\}$ , and the joint probability distribution function  $P(X,Y)$ ,  $(X,Y = 1,2,3)$  is given by the following table. Answer the questions with derivation.

$X \backslash Y$	1	2	3	total
1	1/12	1/6	1/12	1/3
2	1/6	0	1/6	1/3
3	1/12	1/6	1/12	1/3
total	1/3	1/3	1/3	1

- (1) Compute the expectations  $E[X]$ ,  $E[Y]$  and  $E[XY]$ , and show  $E[XY] = E[X] \cdot E[Y]$ .
- (2) Are  $X$  and  $Y$  independent? Justify your answer.
- (3) Compute the variances  $V[X]$ ,  $V[Y]$ , and  $V[X+Y]$ , and show  $V[X+Y] = V[X] + V[Y]$ .
- (4) Prove whether the following proposition is correct in general for two random variables  $X$  and  $Y$ , and give a counterexample if it is not correct: 'If  $X$  and  $Y$  are independent then  $E[XY] = E[X] \cdot E[Y]$ '.  
How about the converse proposition: 'If  $E[XY] = E[X] \cdot E[Y]$  then  $X$  and  $Y$  are independent'?
- (5) Prove whether the following proposition is correct in general, and give a counterexample if it is not correct: 'If  $E[XY] = E[X] \cdot E[Y]$  then  $V[X+Y] = V[X] + V[Y]$ '.

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**Common Subjects③ Data Structure and Algorithms**

Answer all the questions below.

Question 1. Answer the following questions when performing a search of the maze shown in Fig.1.

1	5	9	13
2	6	10	14
3	7	11	15
4	8	12	16

Fig.1 Search maze

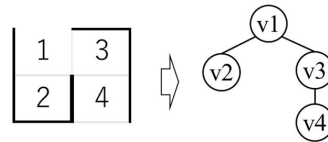


Fig.2 Example of graph structure

- (1) Refer to Fig.2 and draw Fig.1 as a graph structure. The starting point is assumed to be v1.
- (2) When searching for all v using Breadth-first search, answer the last v to be searched. If there are more than one candidate v, the v with the smallest number is searched first.
- (3) When searching Breadth-first using the Queue given in Fig.3, draw the contents of the Queue just after the dequeue of v16.

• enqueue v1 on an empty Queue  
 while (Queue is not empty)  
   • Dequeue from the Queue.  
   • For the dequeued v, enqueue the neighboring v that have not been searched in the order of ascending number.

Fig.3 Queue based breadth-first search algorithm

- (4) When searching for all v using Depth-first search, answer the last v to be searched. If there are more than one candidate v, the v with the smallest number is searched first.
- (5) When searching Depth-first using the Stack shown in Fig.4, draw the contents of the Stack just after v16 is popped.

• push v1 to the empty Stack  
 while (Stack is not empty)  
   • pop from Stack  
   • For the popped v, push the neighboring v that have not been searched in order of descending number.

Fig.4 Stack based Depth-first search algorithm

Question 2. Quick sort is an algorithm for sorting by repeated division based on elements called pivots. Answer the following questions when sorting by ascending order quick sort on the  $S = \{4, 7, 2, 5, 8, 3, 1, 9, 6\}$ . The pivot selection is assumed to be the first element of the number sequence, and the pivot selection is performed when the number of elements in the number sequence is two or more.

- (1) Show the process of a number sequence S being sorted in ascending order by quick sort, using a figure and text.
- (2) There are several orderings of the number sequence S when the total number of pivot choices is maximized. Show any one of them and explain the reason.
- (3) There are several orderings of the number sequence S when the total number of pivot choices is minimized. Show any one of them and explain the reason.

# 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 Science ④ Computer Architecture**

Answer the question below.

Question:

Survey how current computer memory systems are commonly constructed, using all the technical terms below correctly, and also describing the related technologies. Make a complete explanation using only one side of the answer sheet.

[Technical terms] HDD, RAM, ROM, SSD, access speed, external memory, memory hierarchy, volatile, cache, magnetic, main memory, tape, disk, electric, secondary memory, semiconductor, non-volatile, auxiliary memory, capacity, register

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**Computer Science ⑤ Operating System**

Answer all the questions below.

Question:

There are three cases in which OS codes run. For each case, (a)answer the name of the case, (b)describe the type of timing when the case occurs, and (c)show specific examples of each case. Write the answers in the answer sheet, using the format below.

Case(1)

(a) Name: \_\_\_\_\_

(b) Timing:

(c)Specific examples:

Case(2)

(a) Name: \_\_\_\_\_

(b) Timing:

(c)Specific examples:

Case(3)

(a) Name: \_\_\_\_\_

(b) Timing:

(c)Specific examples:

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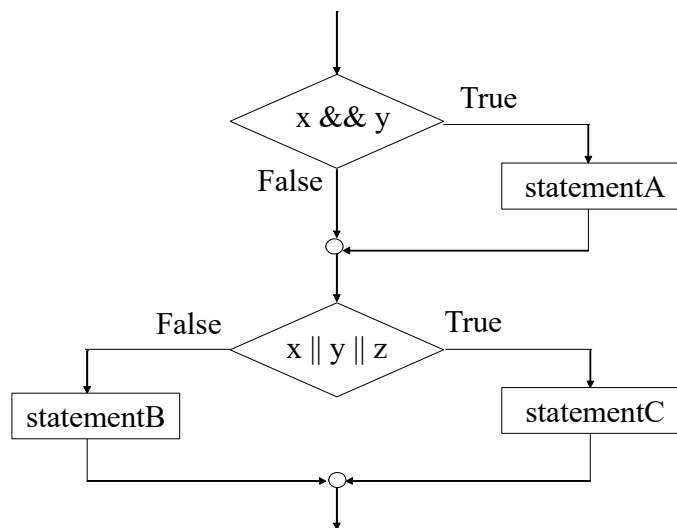
**Computer Science ⑥ Software Engineering**

Answer all the questions below.

Question 1.

In the following flowchart, x, y and z are Boolean variables. “&&” is logical AND operation. “||” is logical OR operation.

Show the minimum test data that satisfies decision/condition coverage criteria (both branch coverage and condition coverage).



Question 2. Describe two advantages of the function point (FP) methodology in development management.

Question 3. Explain the meaning of “STS decomposition” in structured design.

Question 4. Explain the meaning of “is-a relation” in an object-oriented approach.

Question 5. Explain the meaning of “software maintenance.”

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**Computer Science ⑦ Computer Networks**

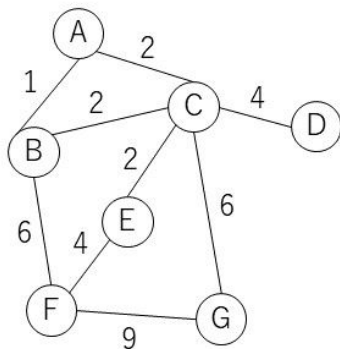
\* This question consists of 2 pages.

Answer all the questions below.

Question 1.

Using Dijkstra's algorithm, find the shortest path for routing packets from node A to every other node in the network below.

The number near the link denotes the distance for the link. Complete the table below, showing each step of the algorithm. In the second column of the table, write the path set S of nodes to which the algorithm finds the shortest path (destination node, next node, distance). Here, the destination node is the new node in the shortest path set, the next node is the next-hop node from node A to reach the destination node, and the distance is the shortest path distance from node A to the destination node. Write the answers in the answer sheet.



Step	S, (Destination node, next node, distance)
1	S={A}, (A,A,0)
2	S={A,B}, (B,B,1)
3	
4	
5	
6	
7	

Question 2.

For the descriptions regarding computer networks from (1) to (8), complete each description by selecting correct answers from the options inside the rectangles. You can answer by writing suitable 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) A formal technical specification issued by the IETF, a voluntary organization that promotes the standardization of various

Internet technologies, is Q(a) ① ITU ② RFC ③ ISO ④ IEEE.

(2) Consider the transmission of data from one host A to another host B in the same network. The data transmitted from A to B

is framed by the functions of Q(b) ① physical ② data link ③ network ④ transport layer, and redundant bits are

transmission errors. Q(c) ① ARP ② ICMP ③ DNS ④ HTTP is used to obtain A's Q(b) layer address.

(3) Q(d) ① ASK ② PSK ③ FSK ④ QAM is a digital modulation process which conveys data by changing the phase of a constant frequency reference signal (the carrier wave).

(4) A Q(e) ① bridge ② repeater ③ router ④ gateway extends a network at the data link layer of the OSI reference model, and forwards a frame correctly received from one LAN to another LAN.

(5) A DNS record pointing to the IPv4 address of the host is Q(f) ① A ② AAAA ③ PTR ④ CNAME record. A DNS

record defining the authoritative name server of a zone is Q(g) ① MX ② NS ③ SOA ④ TXT record.

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(6) Regarding TCP and UDP on IPv4, Q(h) ① only TCP retransmits ② only TCP retransmits ③ both TCP and UDP retransmit IP datagrams that are lost due to errors in the IP layer.

(7) The broadcast address for the IPv4 address 192.168.0.0/22 in CIDR is Q(i) ① 192.168.0.1 ② 192.168.0.255 ③ 192.168.3.254 ④ 192.168.3.255.

(8) The transport protocol specified in RFC2205 for reserving network resources and real-time communication such as multimedia information between nodes is Q(j) ① RTP ② RTCP ③ RSVP ④ SCTP.

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**Computer Science ⑧ Databases**

Answer all the questions below.

Question 1. Choose a correct word from the choices and answer with a symbol (a) to (n) to fill in each of the numbered brackets, for the explanation on the normalization in relational databases below. (Brackets with the same number are filled by the same word, while brackets with different numbers may also be filled by the same word.)

Relations can be normalized based on [①] representing that a value of a set of attributes X determines a value of another attribute A. For example, a relation

Student(student\_no, student\_name, course\_name, course\_director\_name)

has [①] such that a value of [②] determines a value of student\_name, and a value of course\_name determines a value of [③]. In this case, this relation satisfies the condition up to the [④] normal form. In addition, this relation can be decomposed to

R1(student\_no, student\_name, [⑤])

R2([⑥], [⑦])

that satisfy the condition of a higher normal form.

[Choices]

(a)	functional uniqueness	(b)	functional consistency	(c)	functional dependency	(d)	functional atomicity
(e)	student_no	(f)	student_name	(g)	course_name	(h)	course_director_name
(j)	first	(k)	second	(m)	third	(n)	Boyce-Codd

Question 2. Three relations are given below.

Student(student\_no, student\_name)

Subject(subject\_no, subject\_name)

Score(student\_no, subject\_no, point)

Choose a correct item from the choices and answer with a symbol (p) to (x) to fill in each of the numbered brackets, for constructing a SQL statement to get an average point of subjects taken by a student whose name is "Taro Ritsumei". (Brackets with the same number are filled by the same item.)

SELECT AVG ([⑧]) FROM [⑨] WHERE [⑩] IN (SELECT [⑩] FROM [⑪] WHERE [⑫] = "Taro Ritsumei")

[Choices]

(p)	Student	(q)	student_no	(r)	student_name	(s)	Subject
(t)	subject_no	(u)	subject_name	(w)	Score	(x)	point

Question 3. B-tree is a data structure which is used for database indices. Answer with a value to fill in each of the numbered brackets in the following sentence.

After value 16 is inserted into B-tree in Fig. 1, (a) is [⑬], (c) is [⑭] and (g) is [⑮] in the B-tree in Fig. 2.

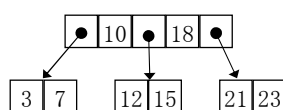


Fig. 1: B-tree

Insert 16

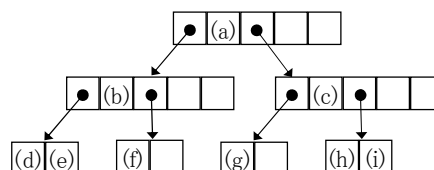


Fig. 2: B-tree after inserting 16

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**Computer Science 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 word or number for the boxes (1) to (15) from the options and answer with the symbols shown in alphabetic letters. Note that some unrelated options are included, and some of the letters are omitted. Assume that the same word is enclosed in the box with the same number.

- (i). First-order logic consists of constant symbols, variable symbols, function symbols, predicate symbols, (1), and 5 logical connectives. There are two types of (1): (2) (1) denoted by  $\forall$ , and (3) (1) denoted by  $\exists$ .
- (ii). A semantic network is a graphical notation of knowledge representation that illustrates concepts and relations between them. A/An (4) relation representing meronymy and holonymy does not have inheritance, while a/an (5) relation representing hyponymy and hypernymy has inheritance.
- (iii). A game where multiple players participate sometimes forms an equilibrium if no player has incentive to switch their strategies. (6) is an equilibrium where each player has a strategy that can increase his/her utility independent of the opponents' actions. On the other hand, (7) is an equilibrium where each player has a strategy that can increase his/her utility according to the opponents' actions. In the case of two players, utilities acquired by each player in all of the combinations of their actions are arranged in a matrix, named (8). From among the following ① to ④, (9) results in (6).

	B: action 1	B: action 2		B: action 1	B: action 2		B: action 1	B: action 2		B: action 1	B: action 2
A: action 1	5, 3	3, 5	A: action 1	2, 3	7, 1	A: action 1	4, 4	8, 1	A: action 1	3, 2	8, 1
A: action 2	3, 5	5, 3	A: action 2	5, 0	0, 2	A: action 2	1, 8	1, 1	A: action 2	5, 4	0, 2
①			②			③			④		

- (iv). In a game where two players make decisions in turn, the players can make a strategy using a game tree. (10) is a strategy where the first mover takes an action that increases his/her utility assuming that the second mover tries to decrease the first mover's utility. Pruning is useful to avoid unnecessary search on the game tree in (10). (11) is a pruning of the first mover's action, while (12) is a pruning of the second mover's action. In Figure 1's game tree where the numbers under leaf nodes denote the utilities acquired by the first mover, The (13) edge is pruned as a/an (12).

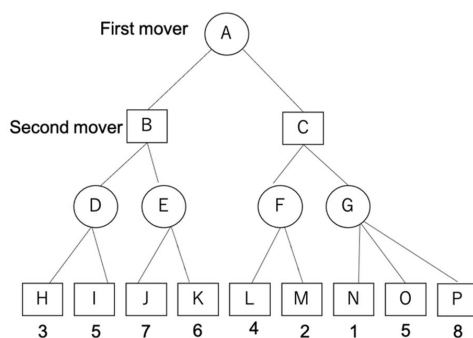


Figure 1: Game tree

- (v). Machine learning is classified into three types: supervised learning, unsupervised learning, and (14). (14) is a learning algorithm that is often modeled based on (15) and can obtain an optimal policy that maximizes the expected future reward.

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[Options]

a	Dominant strategy equilibrium	b	Quantum symbol	c	Estimated cost	d	Dijkstra's algorithm
e	Null move pruning	f	is-a	g	$\beta$ cut	h	neuron
j	Adjacency matrix	k	Reinforcement learning	l	union-of	m	has-a
n	Quantifier	o	Markov decision process	p	Transfer learning	q	Reward
r	Forward pruning	s	Nash equilibrium	t	Universal	u	$\alpha$ cut
v	Dynamic programming algorithm	w	Payoff matrix	x	Perfect equilibrium	y	Existential
z	do	A	Minimax algorithm	B	Deep learning	D	Operation symbol
E	①	G	②	H	③	J	④
L	B-D	M	B-E	Q	C-F	R	C-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 4 pages.

Answer all the questions below.

Q1. Choose the best answer for questions (1) and (2), and answer with the options from (a) to (e).

- (1) Multiples images of potatoes and tomatoes are used to learn patterns. When redness and circularity are used as features, the feature map can be plotted as the distribution shown in Figure 1. With this learning result, an unknown image can be recognized by the nearest neighbor method using the Euclidean distance. In that case, which of the following is the most suitable decision boundary for discriminating the potatoes and tomatoes?

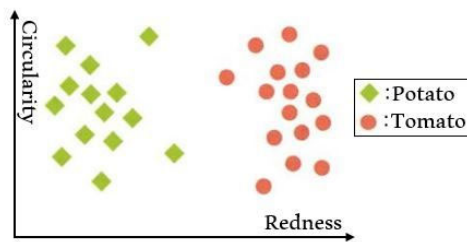
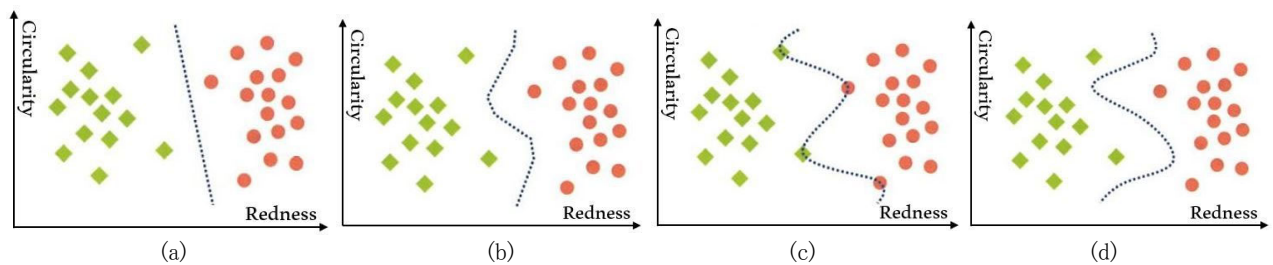


Figure 1

【Options】



- (2) With the learning result shown in Figure 1, a new image is recognized using the  $k$ -nearest neighbor method ( $k = 3$ ) with Euclidean distance. In Figure 2, three input images A, B, and C are given. Which classes are they recognized as? Choose the best result from the following options.

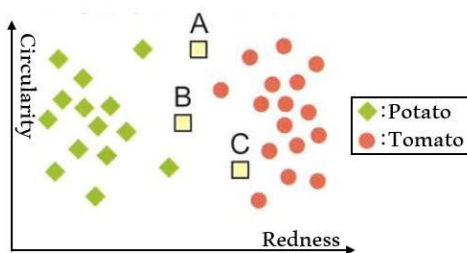


Figure 2

【Options】

	A	B	C
(a)	Tomato	Tomato	Tomato
(b)	Tomato	Tomato	Potato
(c)	Tomato	Potato	Tomato
(d)	Potato	Potato	Potato
(e)	Potato	Potato	Tomato

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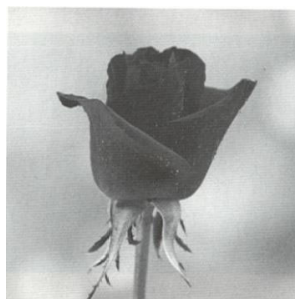
Q2. Choose the best answer for the following (1) and (2) questions, and answer with the option.

- (1)  $f(x, y)$  is the original image and  $g(x, y)$  is the degraded image. The process of image degradation due to camera blur or out of focus can be expressed by equation ① using the point spread function  $h(x, y)$ . Here,  $x, y$  are the coordinates of images. Which of the following  $G(u, v)$  can represent the two-dimensional Fourier transform of  $g(x, y)$ ? Note that  $F(u, v)$ ,  $H(u, v)$  are the two-dimensional Fourier transforms of  $f(x, y)$ ,  $h(x, y)$ , and  $*$  represents the convolution integral.

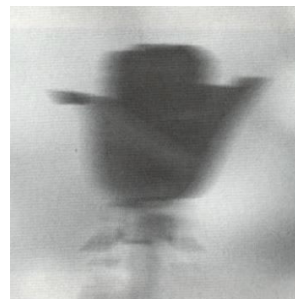
$$g(x, y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x - \xi, y - \eta) h(\xi, \eta) d\xi d\eta \dots \dots \dots \textcircled{1}$$

【Options】

- (a)  $G(u, v) = F(u, v)H(u, v)$   
 (b)  $G(u, v) = F(u, v) * H(u, v)$   
 (c)  $G(u, v) = \frac{H(u, v)}{F(u, v)}$   
 (d)  $G(u, v) = \frac{F(u, v)}{H(u, v)}$
- (2) In equation ①, when  $f(x, y)$  is represented as Figure 3(a) and  $g(x, y)$  is represented as Figure 3(b), which image can represent  $h(x, y)$  in the following options? Here,  $h(x, y)$  is normalized so that the sum of its coefficients is 1. The coordinate of the origin is in the center of the image, and 0 is represented by black.



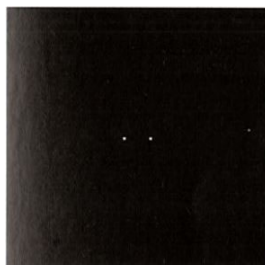
(a)



(b)

Figure 3

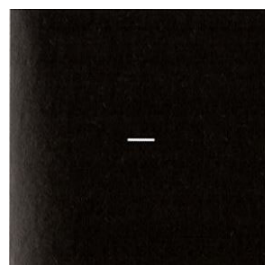
【Options】



(a)



(b)



(c)



(d)

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Q3. Choose the best answer for the following (1) and (2) questions, and answer with the option.

- (1) Given 7 two-dimensional data as shown in Figure 4, the purpose is to build a binary tree by the kd-tree method. First, the data are divided by hyperplane  $l_1$  based on feature 1, and divided data are stored in the left and right child nodes. Then, the data stored in the child nodes are sequentially divided by hyperplane  $l_2$  based on feature 2, and continuously divided by the hyperplane based on feature 1, and so on. In the process of building the tree with kd-tree method, which of the following options is the most appropriate hyperplane to separate the data?

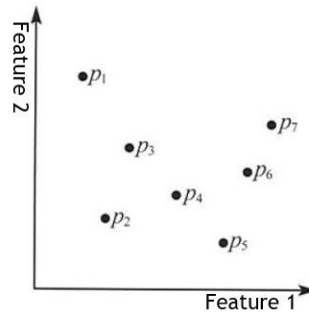
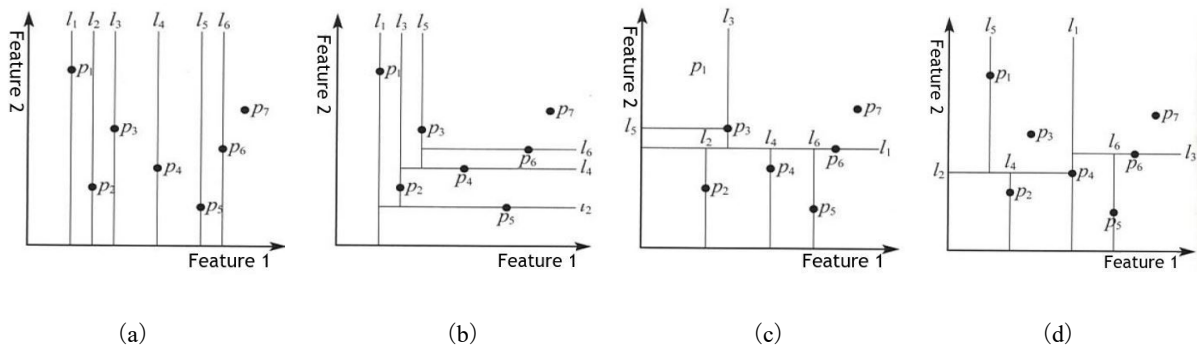


Figure 4

【Options】



- (2) Hashing can be used to approximate nearest neighbor. In equation ②, the hash function is represented as  $h$ . Which of the following data is the output of the nearest neighbor of test data  $\mathbf{b} = (10110011)$ . Note that,  $M$  is 16, and test data  $\mathbf{b}$  has already been converted to binary vector. The hash values of the data are shown in Table 1.

$$h(\mathbf{b}) = \left( \sum_{i=1}^d b_i 2^{i-1} \right) \bmod M \dots\dots\dots \textcircled{2}$$

Table 1

Hash Value	Data
3	Data 1
5	Data 2
9	Data 3
11	Data 4
15	Data 5

【Options】

- (a) Data 1   (b) Data 2   (c) Data 3   (d) Data 4   (e) Data 5

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Q4. Choose the best answer for the following (1) and (2) questions, and answer with the option.

- (1) When rotating an image using the linear transformation with equation ③, which transformation equation can be used to represent rotating the image by  $\theta$  degrees clockwise about the origin as shown in Figure 5?

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \dots\dots\dots \textcircled{3}$$

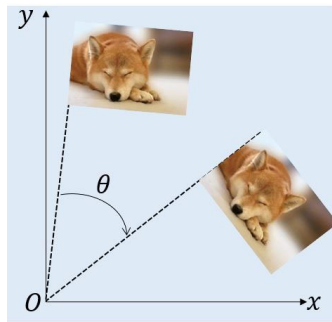


Figure 5

【Options】

- (a)  $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \sin\theta & -\cos\theta \\ \cos\theta & \sin\theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$       (b)  $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ \tan\theta & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$       (c)  $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \sin\theta & \cos\theta \\ -\cos\theta & \sin\theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$
- (d)  $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$       (e)  $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & \tan\theta \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$       (f)  $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$

- (2) Which of the following option is the most appropriate to describe the parallel stereo shown in Figure 6, in which two cameras are aligned with an interval  $b$  and have a focal length  $f$ . Note that the  $u$ -axis and  $u'$ -axis of the image coordinates lie on the same line and parallel to the  $X$ -axis of the world coordinate. And the  $v$ -axis and  $v'$ -axis of the image coordinates are parallel to the  $Y$ -axis of the world coordinate. The origin of  $(u, v)$  coordinate lies on the  $Z$  axis of the world coordinate, and the parameters of two cameras are the same.

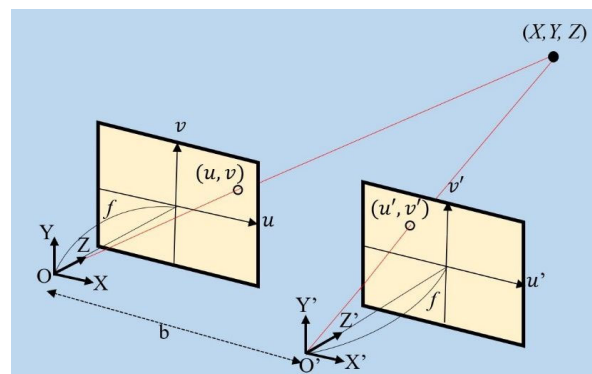


Figure 6

【Options】

- (a)  $X$  is uniquely determined by the parallax  $u - u'$  and is proportional to the parallax
- (b)  $X$  is uniquely determined by the parallax  $u - u'$  and is inversely proportional to the parallax.
- (c)  $Y$  is uniquely determined by the parallax  $u - u'$  and is proportional to the parallax
- (d)  $Y$  is uniquely determined by the parallax  $u - u'$  and is inversely proportional to the parallax
- (e)  $Z$  is uniquely determined by the parallax  $u - u'$  and is proportional to the parallax
- (f)  $Z$  is uniquely determined by the parallax  $u - u'$  and is inversely proportional to the parallax

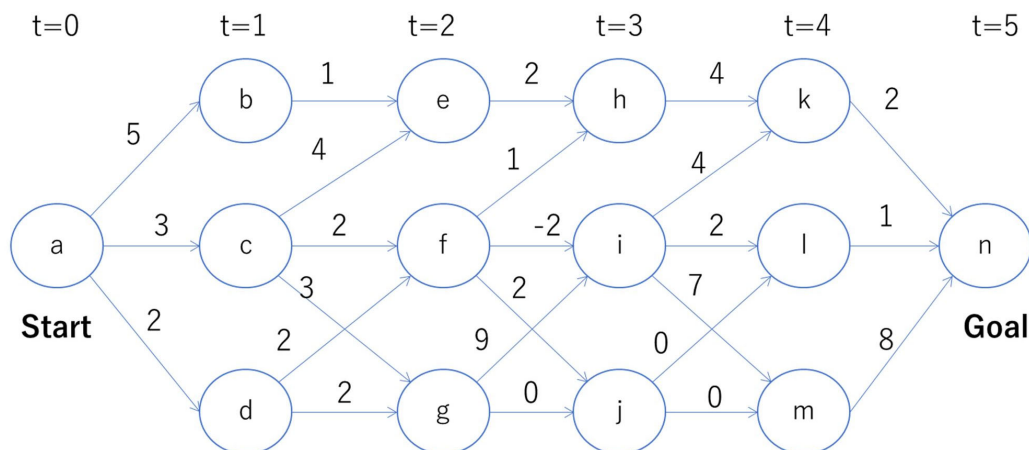
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**Human Information Science ⑪ Artificial Intelligence**

Answer all the questions below.

Question 1. An agent needs to find the path from state **a** to state **n** that gives the agent the maximum cumulative rewards. The number beside (and just above) each arrow means the reward the agent obtains when the agent moves through the arrow. The cumulative rewards mean the sum of the rewards the agent obtains. Each circle and arrow represent a state and a state transition, respectively. The value  $t$  represents a time step. The agent can only move from the left to the right at each step. The problem is to find a path that gives an agent the maximum cumulative reward.

- (1) Execute *dynamic programming* and describe memoized values for all of the states. A memoized value means the maximum cumulative reward to reach the target state (i.e., subgoals).
- (2) Find and describe the optimal path from state **a** to goal **n**.
- (3) When the number of states at each time step becomes  $M$ , and the total time steps becomes  $N$ , the total computational cost will increase. Please describe the computational cost of *dynamic programming* and explain it.



Question 2.

- (1) Please explain what **Bayes' theorem** means with an example.
- (2) Please explain what a **gradient method** (or a steepest descent method) in optimization means with an example.
- (3) Please describe the algorithm of **k-means clustering**.
- (4) Please explain what **syntactic parsing** in natural language processing means with an example.

AY2022 Examination Questions for the Graduate School of  
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(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.

Choose two questions from the common subjects and choose either the Computer Science section or the Human Information Science section.

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.

Common Subjects	① Linear Algebra ② Probability and Statistics ③ Data Structure and Algorithms	
Specialized Subjects	Computer Science	④ Computer Architecture ⑤ Operating System ⑥ Software Engineering ⑦ Computer Networks ⑧ Databases ⑨ Artificial Intelligence
	Human Information Science	⑩ Image Processing ⑪ Artificial Intelligence

【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. 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**

Describe the process, not just the answer, for the following questions.

Question 1. Let  $A = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 0 & 2 & 3 & 4 & 5 & 6 \\ 0 & 0 & 3 & 4 & 5 & 6 \\ 0 & 0 & 0 & 4 & 5 & 6 \\ 0 & 0 & 0 & 0 & 5 & 6 \\ 0 & 0 & 0 & 0 & 0 & 6 \end{bmatrix}$ . Answer the following questions.

- (1) Find the inverse matrix  $A^{-1}$  of  $A$ .
- (2) Find the maximum and minimum eigenvalues of  $A^{-1}$ , which is the inverse matrix of  $A$ .
- (3) Find the eigenvector corresponding to the maximum eigenvalue of  $A^{-1}$ , which is the inverse matrix of  $A$ .

Question 2. Find the ranks of the following matrices. (Please also show the reasoning behind your decision)

(1)  $\begin{bmatrix} 2 & 1 & 1 & 8 \\ 5 & 6 & 7 & 8 \\ 1 & 2 & 3 & 4 \\ 1 & 1 & 1 & 1 \end{bmatrix}$

(2)  $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$

(3)  $\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \end{bmatrix}$

(4)  $\begin{bmatrix} 1 & 0 & 2 \\ -1 & 1 & 0 \\ 0 & 0 & 2 \end{bmatrix}$

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**Common Subjects② Probability and Statistics**

Answer all the questions below with the derivation process.

Question 1. Find each constant  $C_i$  ( $i = 1, 2, \dots, 8$ ), the expectation and the variance of the following probability functions.

(1) Probability distribution :  $P(X = k) = \begin{cases} C_1, & (k = 0, \pm 1, \pm 2), \\ 0, & (\text{Otherwise}) \end{cases}$

(2) Probability distribution :  $P(X = k) = \begin{cases} C_2, & (k = 9998, 9999, 10000, 10001, 10002), \\ 0, & (\text{Otherwise}) \end{cases}$

(3) Probability distribution :  $P(X = k) = \begin{cases} C_3, & (k = 0, \pm 100, \pm 200), \\ 0, & (\text{Otherwise}) \end{cases}$

(4) Probability distribution :  $P(X = k) = \begin{cases} C_4 \cdot k^2, & (k = 0, \pm 1, \pm 2), \\ 0, & (\text{Otherwise}) \end{cases}$

(5) Probability density distribution :  $f(x) = \begin{cases} C_5, & (|x| \leq 2), \\ 0, & (\text{Otherwise}) \end{cases}$

(6) Probability density distribution :  $f(x) = \begin{cases} C_6 \cdot x^2, & (|x| \leq 2), \\ 0, & (\text{Otherwise}) \end{cases}$

(7) Probability density distribution :  $f(x) = C_7 \cdot \exp\left(-\frac{1}{4}x^2 + x\right), (x \in \mathbb{R})$

(8) Probability density distribution :  $f(x, y) = C_8 \cdot \exp\left(-\frac{1}{4}x^2 - y^2 + x - 2y - 2\right), (x, y \in \mathbb{R})$

For the two-variable function, in addition to the constant  $C_8$ , give the covariance, the expectation and the variance of each variable.

Question 2. Five samples are obtained for two-dimensional data  $(X, Y)$  as follows:

$$(X, Y) = (1, 1), (2, 3), (3, 2), (4, 5), (5, 4).$$

Find the sample average and variance of each  $X$  and  $Y$ , and the covariance and correlation coefficient between  $X$  and  $Y$ .

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<b>Common Subjects③ Data Structure and Algorithms</b>
---

Answer all the questions below.

Question 1.

Answer the following questions about binary search trees. It is assumed that the binary search tree satisfies the following requirements.

The value of the left child of point  $v$   $<$  The value of point  $v$   $<$  The value of the right child of point  $v$

- (1) The number sequence  $\{21, 5, 37, 28, 8, 19, 3\}$  is inserted into the empty binary search tree in this order. Show the diagram of this binary search tree.
- (2) Show the diagram of the binary search tree after deleting element  $\{21\}$  from the binary search tree in (1).
- (3) A binary search tree of height 2 was created by re-ordering the elements of the sequence of numbers in (1). Show a diagram of this binary search tree.

Question 2.

Answer the following questions about heap. In addition, each element of the heap must satisfy the following requirements.

The value of point  $v$  is always less than or equal to the value assigned to the children of point  $v$ .

- (1) A sequence of numbers  $\{41, 25, 44, 50, 22, 31\}$  was inserted into an empty heap in this order. Show a diagram of this heap.
- (2) Show the diagram of the heap after the smallest element is deleted from the heap in (1).

Question 3.

For the time complexity of an algorithm on data of size  $n$ , give the words that fit in (a)-(d) in the following sentences.

The time complexity of the linear search algorithm is  $O(a)$ . The time complexity of the binary search, which divides the data to be searched into halves, is  $O(b)$ . For the heap, the time complexity required to reconstruct it by adding one element is  $O(c)$ . Also, the amount of time required to delete the smallest element and reassemble the heap is  $O(d)$ .

# 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.

Explain the difference between a direct-mapped cache and a fully-associative cache in terms of how to map a memory block to a cache block. Also explain the difference between the two caches in terms of cache hit ratios and hardware complexity.

Question 2.

Explain what control hazard is by using an example. Also explain how to eliminate or reduce the effect of control hazard.

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**Computer Science⑤ Operating System**

Answer all the questions below.

Question:

Summarize and explain the related technologies of virtual memory systems commonly used now by using all the technical terms below correctly. Make a complete explanation using only one side of the answer sheet.

[Technical terms]

TLB, FIFO, LRU, OPT, replacement, virtual address, virtual memory, memory management, locality, reference string, real address, main memory, segmentation, page table, secondary memory, contiguous allocation, fetch, paging, auxiliary memory, non-contiguous allocation

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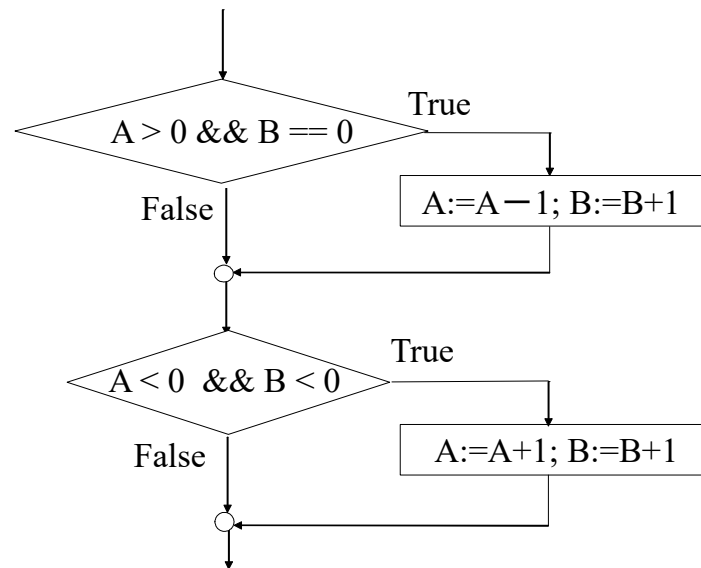
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**Computer Science⑥ Software Engineering**

Answer all the questions below.

Question 1:

In the following flowchart, “&&” is the logical AND operation. A and B are integer type variables and their values should be either -1, 0 or 1. Show the minimum test cases that completely satisfy branch coverage criteria.



Question 2: Describe two advantages of throwaway prototyping comparing with evolutionary prototyping.

Question 3: Explain the disadvantages of stamp coupling in software modular design.

Question 4: Explain the meaning of aggregation in an object-oriented approach.

Question 5: Explain two purposes of software testing.

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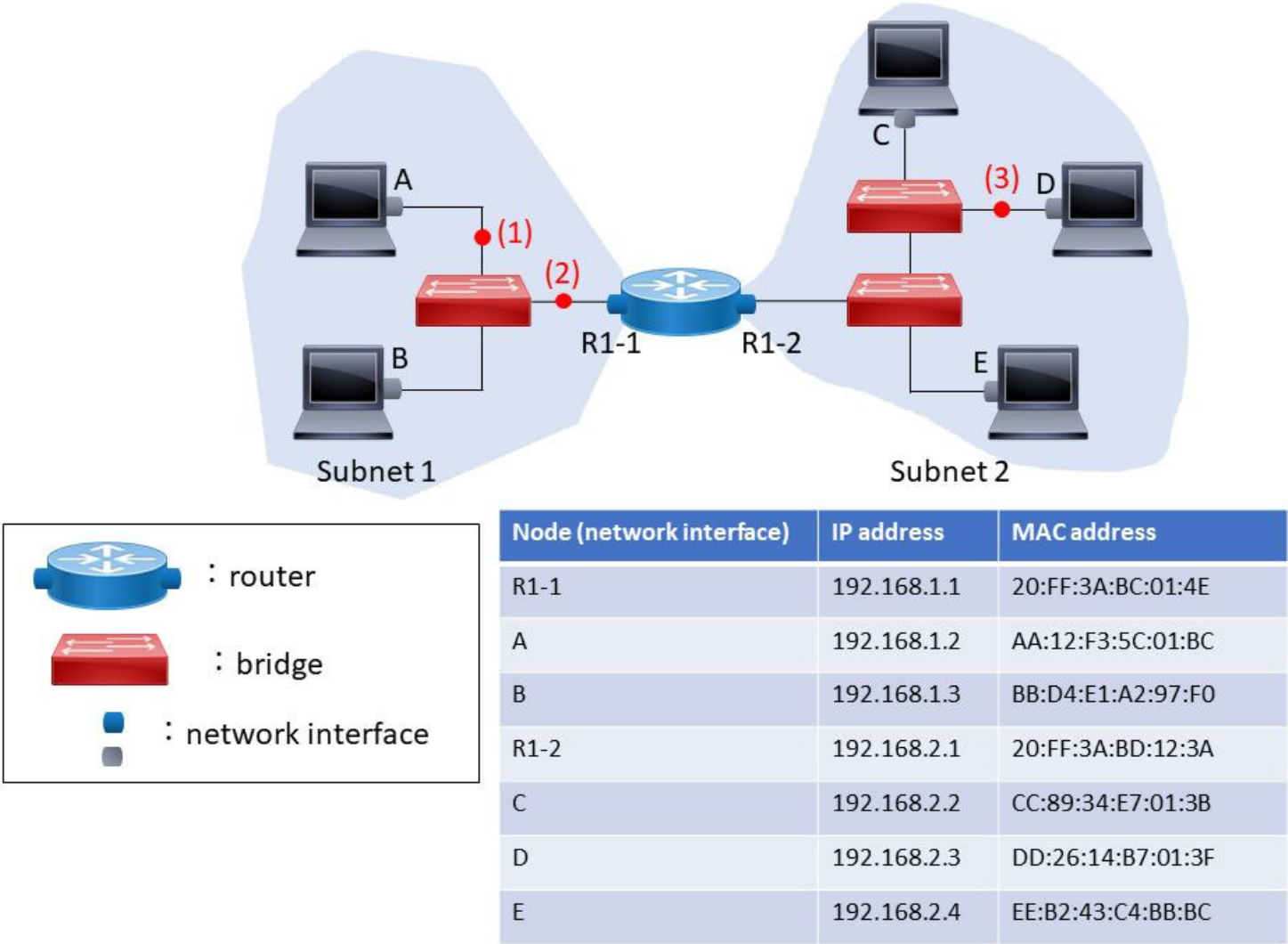
**Computer Science⑦ Computer Networks**

\* This question consists of 2pages.

Answer all the questions below.

Question 1.

Consider an IP datagram being sent from A to D using Ethernet as the data link-layer protocol in all links in the figure below. What are the source MAC address, destination MAC address, source IP address, and destination IP address of the IP datagram encapsulated within the Ethernet frame at points (1), (2), and (3) in the below example for a datagram going from A to D. Write all four addresses at each of the three points.



Question 2.

You rip a 3 minute long stereo music track by sampling it at 8kHz with 16bits per channel and store it in a file in raw format. How long would it take to send the file over a 1Mbps communication link? Select the correct answer.

- (1) About 23 seconds.
- (2) About 46 seconds.
- (3) About 3 minutes.
- (4) About 6 minutes.
- (5) It depends on the volume setting.

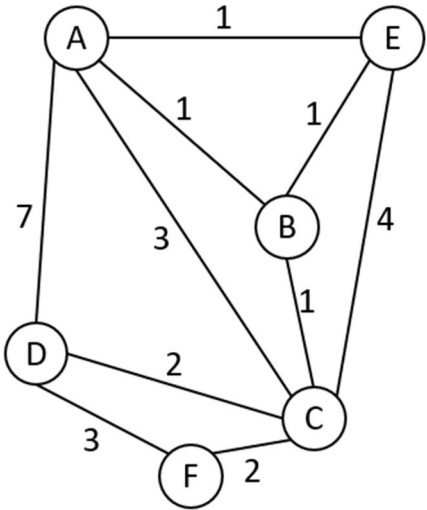


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\* This question consists of 2pages.

Question 3.

Consider the network shown below and assume that each node initially knows the costs to each of its neighbors. Use the distance vector algorithm and complete the following distance table for node C after the algorithm has converged. Write the costs for (1) through (14). Make sure to consider the Poison Reverse algorithm in your calculation. In other words, some of the entries might have a cost of  $\infty$ .



Distance Vector table at node C		Cost to destination node					
		A	B	C	D	E	F
Distance Vector from neighbor	A	(1)	(2)	(3)	(4)	(5)	(6)
	B	1	0	$\infty$	$\infty$	1	$\infty$
	D	$\infty$	$\infty$	$\infty$	0	$\infty$	3
	E	(7)	(8)	(9)	(10)	(11)	(12)
	F	$\infty$	$\infty$	$\infty$	(13)	$\infty$	(14)

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Computer Science⑧ Databases

Answer all the questions below.

Question 1. Choose a correct word from the choices and answer with a symbol (a) to (s) to fill in each of the numbered brackets, for the explanation on the relational database design below. (Brackets with the same number are filled with the same word, while brackets with different numbers may also be filled with the same word.)

Consider a database to manage the vaccination history of citizens. In case of adding a "Date\_of\_Vaccination" to the entity-relationship diagram in Figure 1, this data should be an attribute of [①]. When the relationship "Injected" is transformed to a relation, the primary key of this relation will be [②]. For a relation transformed from the entity "Vaccine", there are functional dependencies that [③] uniquely determines [④] and [④] uniquely determines [⑤]. Therefore, this relation satisfies the condition up to [⑥] normal form. (Note that a citizen is vaccinated multiple times with different lot numbers of vaccine, and the same lot number of vaccine is injected to multiple citizens.)

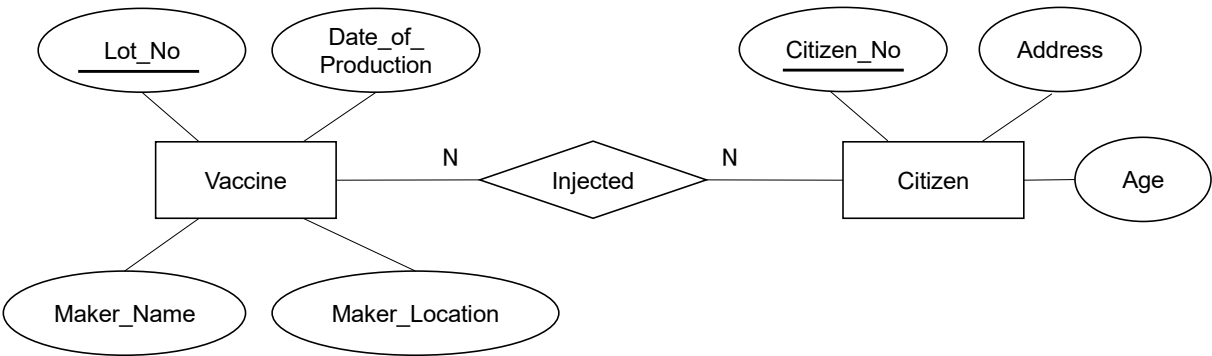


Fig. 1: Entity-Relationship Diagram

[Choices]

(a)	Vaccine	(b)	Citizen	(c)	Injected	(d)	Lot_No
(e)	Citizen_No	(f)	Lot_No, Citizen_No	(g)	Date_of_Vaccination	(h)	Date_of_Production
(j)	Maker_Name	(k)	Maker_Location	(m)	Address	(n)	Age
(p)	first	(q)	second	(r)	third	(s)	Boyce-Codd

Question 2. For the following explanation on database concurrency control, choose a word or phrase that best fits the enclosed parts with symbols (a) through (e), and answer with the number of your choice. The choices and their numbers are described in the enclosing box. If you do not find a suitable choice, write a suitable word or phrase. Assume that the same word or phrase goes in boxes with the same symbol.

[ (a) ① Relations ② Schemas ③ Transactions ④ Indexes ] represent a collection of indivisible actions, which must satisfy the property called [ (b) ① uniformity ② atomicity ③ integrity ④ exclusiveness ], where either all actions are executed or none are. For the concurrency control to keep the consistency of data when multiple [ (a) ] are executed simultaneously, the method called [ (c) ① logging ② two-phase commit ③ two-phase locking ④ slicing ] is used. In case of using [ (c) ], [ (d) ① unlock ② disk failure ③ bug ④ deadlock ] may occur where all [ (a) ] wait for each other. To release [ (d) ], it is necessary to terminate [ (e) ① all ② one of ] the [ (a) ] in the waiting status.

Question 3. When expressing the following relational algebra operation in a SQL statement, answer the appropriate expressions that should be placed in the numbered brackets.

Relational algebra operation:  $\pi_{P.a,Q.d}(\sigma_{Q.d < 20}(P \bowtie_{P.b=Q.c} Q))$

SQL Statement: SELECT [①] FROM [②] WHERE [③] AND [④]

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Computer Science⑨ Artificial Intelligence

\* This question consists of 2pages.

Answer all the questions below.

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

- (i) There are a best first search algorithm and A\* algorithm for pathfinding. The best first search expands the nodes with the lowest (1) and A\* algorithm with the lowest (2), respectively. In the following graph, the best first search finds (3) as a path from S to G and A\* algorithm obtains (4). A\* algorithm is guaranteed to find the optimal path if the estimated cost is (5) the actual cost, while the best first search does not guarantee the optimality.

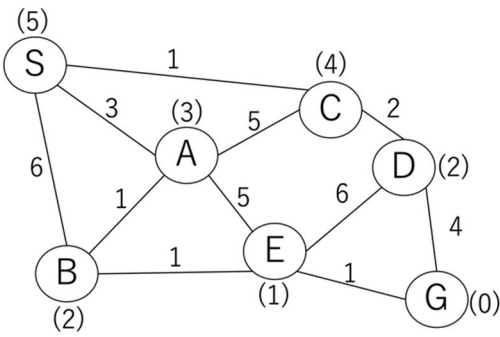


Fig. 1. Graph (The numbers along edges are actual costs and ones in parentheses are estimated costs)

- (ii) The multi-stage decision problem is a problem to maximize the sum of profits when a chosen action at time  $t$  decides the state at time  $t+1$  and obtains a profit. The efficient method to solve the multi-stage decision problem by breaking it down into sub-problems is (6). (6) applies (7) to reuse values that have already been calculated.
- (iii) Bayes' theorem is utilized to predict an event in the uncertain real world. The Bayes' theorem is stated mathematically as the following equation, (8), where  $A$  and  $B$  represent independent events. This theorem is applied to a spam filter. Assume that the following table summarizes each probability of word  $w_1$ ,  $w_2$ , and  $w_3$  occurring for spam and not spam. If spams occur with probability 0.1, the probability of the spam occurring for a mail containing  $w_2$  is (9). Also, the probability of spam for a mail containing  $w_3$  is (10) than one of not spam.

	$w_1$	$w_2$	$w_3$
$P(w_i spam)$	0.5	0.1	0.4
$P(w_i not\ spam)$	0.5	0.3	0.2

- (iv) Symbolic logic is a formalization method that expresses logical relationships among events described in languages by converting them into symbols. Especially, the logic that expresses propositions by splitting it into a subject and predicate and using variables is called predicate logic. For example, "all people like peace." is expressed in predicate logic as below.  
(11) (human(x) (12) like(x, PEACE))  
Note that human(x) and like(x, y) are predicates that express "x is human" and "x likes y" and PEACE is a constant expressing "peace".
- (v) A supervised learning uses (13) containing supervisory signal for learning. This learning method updates parameters to reduce errors between the supervisory signal and output value. The technique to update the parameters based on a gradient of the error function is called (14). This type of learning can be used for (15), which outputs a real value given an input value, and classification, which classifies inputs into categories.

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\* This question consists of 2pages.

[Options]

a	$P(B A) = \frac{P(A B)P(B)}{P(A)}$	b	Gradient Ascent	c	Estimated cost	d	$P(A, B) = P(A B)P(B)$
e	Optimization problem	f	Sum of actual cost and estimated cost	g	$P(A) = \sum_B P(A, B)$	h	$\exists x$
j	More than	k	Training data	l	Linear programming	m	Maximization
n	$\forall x$	o	Memoization	p	Reward	q	$\rightarrow$
r	Actual cost	s	Higher	t	$\wedge$	u	Lower
v	Dynamic programming	w	Test data	x	Less than	y	Gradient descent
z	Regression	A	Minimax	B	Hashing	D	Search problem
E	27/100	G	1/100	H	1/28	J	27/28
L	S->B->E->G	M	S->A->B->E->G	Q	S->C->D->G	R	S->C->E->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 Science⑩ Image Processing**

\* This question consists of 4 pages.

Answer all the questions below.

Question 1. Answer each question.

- (1) The analog video signal standard “NTSC”, once employed in television broadcasting in Japan, adopted YIQ color coordinate system for its color representation. A color (R,G,B) represented in RGB color coordinate is converted to (Y,I,Q) in YIQ color coordinate by the following equations:

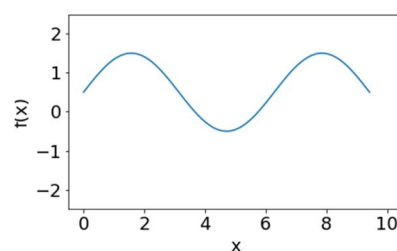
$$X_1 = 0.596R - 0.275G - 0.321B,$$

$$X_2 = 0.212R - 0.523G + 0.311B,$$

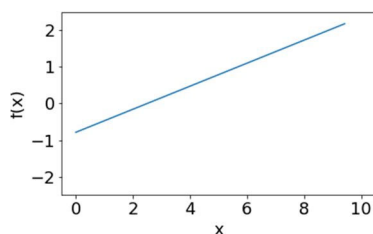
$$X_3 = 0.299R + 0.587G + 0.114B.$$

Of  $X_1, X_2$ , and  $X_3$ , which corresponds to the signal Y of YIQ color coordinate that represents the brightness (intensity) of pixels? Answer with the reason for your choice.

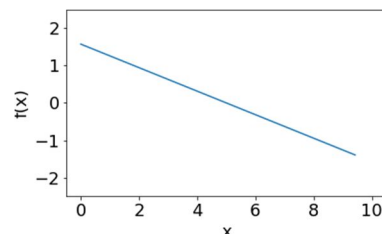
- (2) SSD (Sum of Squared Difference) and correlation coefficient are often used for solving stereo feature correspondences by pixel pattern matching. Choose the most appropriate signal profile that gives the largest correlation coefficient with the 1-D signal  $f(x)$  shown below among the following choices (a) to (d).



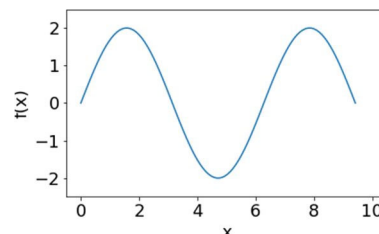
Signal  $f(x)$



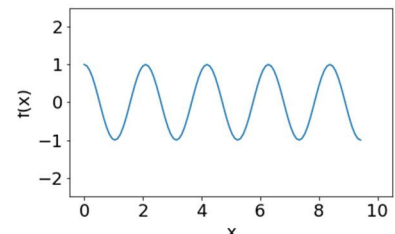
(a)



(b)



(c)



(d)

Choices

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\* This question consists of 4 pages.

Question 2. For a grayscale image sequence  $I(x, y, t)$  which captures a moving object, where  $(x, y)$  is the horizontal and vertical image coordinates and  $t$  is time, we want to obtain the optical flow field  $\left(\frac{dx}{dt}, \frac{dy}{dt}\right) = (u(x, y, t), v(x, y, t))$ , the motion information for each pixel, by gradient method. The spatio-temporal gradient constraint equation for  $u$  and  $v$  is given as following:

$$\frac{\partial I(x, y, t)}{\partial x} u(x, y, t) + \frac{\partial I(x, y, t)}{\partial y} v(x, y, t) + \frac{\partial I(x, y, t)}{\partial t} = 0.$$

- (1) Let  $I(x, y, t)$  be the pixel value at  $(x, y)$  of the image captured at time  $t$ . When the optical flow at pixel  $(x, y)$  is assumed to be  $(u(x, y, t), v(x, y, t))$ , then the point on the object projected onto this pixel should be projected onto the pixel  $(x + u\Delta t, y + v\Delta t)$  in the image taken after small time duration  $\Delta t$ , and its pixel value should be  $I(x + u\Delta t, y + v\Delta t, t + \Delta t)$ . Assuming that these two pixel values are equivalent, derive the spatio-temporal gradient constraint equation above. (Hint: Employ the first-order approximation of Taylor expansion.)

- (2) Only one spatio-temporal gradient constraint equation can be obtained for each pixel and it is not enough to uniquely determine  $(u, v)$  for every pixel. This is called *the aperture problem*. How can we obtain the optical flow  $(u(x, y, t), v(x, y, t))$  given the existence of the aperture problem? Show and explain an effective solution in detail.

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＊ This question consists of 4 pages.

Question 3. In image understanding by using deep neural networks, “Conv layer” based on the convolutional filter is often employed as the feature extraction layer. Choose the most appropriate image for the output obtained by applying each of 3x3 convolutional filters (1) ,(2), and (3) to the input image below.



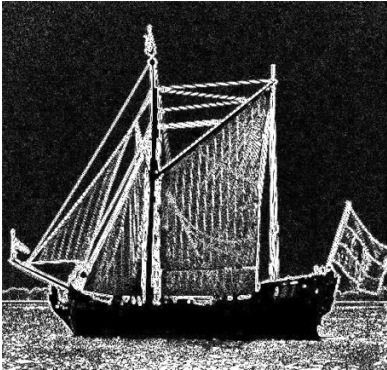

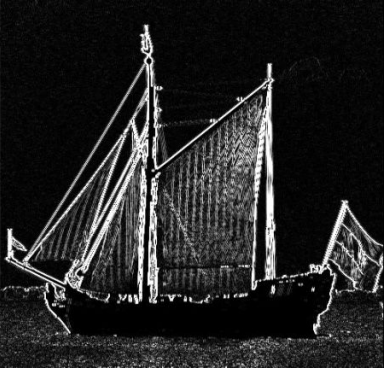
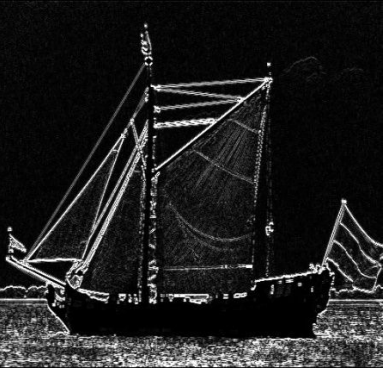


Input image (grayscale)

Convolutional filters

(1)	(2)	(3)																											
<table><tr><td>-1</td><td>0</td><td>1</td></tr><tr><td>-2</td><td>0</td><td>2</td></tr><tr><td>-1</td><td>0</td><td>1</td></tr></table>	-1	0	1	-2	0	2	-1	0	1	<table><tr><td>-1</td><td>-1</td><td>-1</td></tr><tr><td>-1</td><td>8</td><td>-1</td></tr><tr><td>-1</td><td>-1</td><td>-1</td></tr></table>	-1	-1	-1	-1	8	-1	-1	-1	-1	<table><tr><td>-1</td><td>-2</td><td>-1</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>2</td><td>1</td></tr></table>	-1	-2	-1	0	0	0	1	2	1
-1	0	1																											
-2	0	2																											
-1	0	1																											
-1	-1	-1																											
-1	8	-1																											
-1	-1	-1																											
-1	-2	-1																											
0	0	0																											
1	2	1																											

Choices of output images

(a) 	(b) 	(c) 
(d) 	(e) 	(f) 



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\* This question consists of 4 pages.

Question 4. In video streaming services via computer network, compression of image data allows live streaming in realtime even if network has a limited transfer bitrate. When the average transfer bitrate between the streaming server and user's terminal is 20 Mbps (Mega bits per second), what percentage must the amount of compression be compared to the original one for each video frame in order to provide video streaming at 30 fps (frame per second) in average?

Each original video frame has a resolution of 1000x1000 pixels, consists of three planes of RGB color, and the pixel value of each plane is expressed in 8-bit depth (i.e., 24 bits in total for one pixel). You may assume an ideal case where the fluctuation of network speed is extremely small.

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**Human Information Science⑪ Artificial Intelligence**

Question 1. Briefly explain all the phrases below with a specific example.

- (1) Constructive approach
- (2) Symbol grounding problem
- (3) Nash equilibrium
- (4) Markov decision process

Question 2. Select the most suitable phrase to fill in the blanks in the following sentence from the choices below (write the number).

Machine learning is classified into reinforcement learning, supervised learning, and unsupervised learning, depending on how feedback information is handled. Unsupervised learning is generally used for clustering and dimension reduction of data. As a typical clustering method, the [ (1) ] is known, and as a dimension reduction method, [ (2) ] is known. Problems tackled by machine learning are roughly divided into [ (3) ] problems and classification problems. In the classification problem, the naive Bayes classifier is a [ (4) ] model, and the support vector machine is a [ (5) ] model.

【Choices】 ①Bayes' theorem ②fuzzy theory ③differential ④principal component analysis ⑤k-means algorithm  
⑥Integral ⑦multinomial distribution ⑧generative ⑨Gaussian distribution ⑩imitation ⑪transfer ⑫discriminative  
⑬normal distribution ⑭regression ⑮beta distribution

Question 3. Select the most suitable phrase to fill in the blanks in the following sentence from the choices below (write the number).

The basic formula of probability is utilized in the construction of artificial intelligence. It is called the multiplication theorem that a joint probability  $P(A, B)$  is rewritten as  $P(A, B) = P(A|B)P(B)$ . In this equation,  $P(A|B)$  is called [ (1) ]. If  $P(A, B)$  is marginalized for  $B$ , it becomes [ (2) ]. Bayes' theorem is an equation derived from the [ (3) ]. The posterior probability, which is the probability of the cause for the resulting event, can be obtained from likelihood and the prior probability. The graphical model shows the [ (4) ] between random variables. A set of nodes [ (5) ] defined by  $P(A|\partial A, B) = P(A|\partial A)$  is called a Markov blanket.

【Choices】 ①multiplication theorem ② $P(B|A)$  ③addition theorem ④conditional probability ⑤joint probability  
⑥posterior probability ⑦dependencies ⑧ $P(B)$  ⑨expected value ⑩neural network ⑫ $\partial A$  ⑬ $A$  ⑭conditional expectation  
⑮ $P(A)$

Question 4. Convert the following propositional logical formula to the conjunctive normal form.

$$P \equiv Q \vee R$$