Computer and Data Science: Second-Round Sample Tasks for the Open Doors Undergraduate Track

You will be asked to complete 35 tasks, including:
- 21 entry-level tasks, each correct answer worth 1 or 2 points;
- 11 intermediate-level tasks, each correctly answered task worth from 3 to 5 points;
- 3 advanced tasks (constructed response), each correctly completed task valued at 10–15 points.

For multiple-choice questions, the correct answers are highlighted in bold.

Evaluation criteria and standard answers are provided for the advanced tasks requiring constructed responses.

Scientific field 1. Applied mathematics

Task 1
Entry level (2 points)

It is known that ln2=a, ln3=b. Express $\log_{18}24$ in terms of a and b.

a) 3a + b   **b)** $\frac{3a+b}{a+2b}$ c) $\frac{a^3+b}{a+b^2}$ d) $\frac{a+3b}{2a+b}$

Answer: $\frac{3a+b}{a+2b}$

Task 2
Entry level (1 point)

Which of the following numbers does the set of values $y = 16^{-x} + 4$ include?

a) 4   b) –0.5   **c) 5**   d) 1

Answer: 5

Task 3
Entry level (1 point)

Which of the following numbers is the solution of the inequality $\cos x < \frac{1}{2}$?

a) 3   b) 6   c) – 1   d) 1

Answer: 3

Task 4
Entry level (2 points)

Cowboy John hits a fly on the wall with a probability of 0.9 if he shoots with an adjusted revolver. If John fires an unadjusted revolver, then he hits a fly with a probability of 0.3. There are 10 revolvers on the table, only two of them are adjusted. Cowboy John sees a fly on the wall, grabs the revolver at random, and shoots the fly. Find the probability of John missing.

a) **0.58**   b) 0.42   c) 0.7   d) 0.1

Answer: 0.58

Task 5
Intermediate level (5 points)

Let $|\vec{p}| = 2$, $|\vec{q}| = 5$, $cos(\vec{p}, \vec{q}) = -0.3$. Which of the following is the scalar square of the vector $3\vec{p} - \vec{q}$?

a)   59
b)   69
c)   79
d)   89

Answer: 79

Task 6
Intermediate level (5 points)

Which of the following is the sum of even numbers belonging to the increasing interval of the function $y = \frac{(x-15)^2}{(x-12)^3} + \frac{23}{81}$?

a)   44
b)   54
c)   64
d)   74

Answer: 54

Task 7
Advanced level (14 points)

In some tree, the degree of each vertex is either 1 or 5. The number of vertices of degree 5 is 30.

Each vertex of degree 5 is connected either to four vertices of degree 1 and one of degree 5, or to five vertices of degree 5. Such vertices are called weak and strong, respectively.

1. How many vertices are there in such a tree?
2. Find the number of the strong vertices.
3. Let the length of each edge be 1. Assuming that each strong vertex is adjacent to at most two other strong vertices, calculate the greatest path length between the two weak vertices.

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Please note that the evaluation will consider your problem-solving process; providing only the final answer is not sufficient.

Answer:

1. Let n denote the number of tree vertices and m the number of edges. By the handshake theorem, the sum of the degrees of all vertices of the graph is 2m. There are 30 vertices of degree 5 in this tree, and n-30 vertices of degree 1. This means that the sum of all degrees is equal to 5·30+1·(n-30)=n+120. So, n+120=2m.

Since in any tree m=n−1, substituting this in the previous formula, we get the equation n+120=2n−2. After solving the equation, we get the answer: n=122.

2. Let us remove all vertices of degree 1 from the tree. The resulting graph T' is also a tree, with 30 vertices and 29 edges. Thus, 4 neighbors were removed from each weak vertex, and the degrees of all such vertices in T' became 1. For strong vertexes, the degree remains 5.

Let n denote the number of strong vertices. Then, the number of weak vertices will be 30, and the sum of all the degrees of vertices of the tree T' is 5x+1·(30-x) = 4x+30, which in turn is twice the number of vertices, i.e. 4x+30=2·29=58. By solving the equation, we obtain x=7.

3. Let us remove all weak vertices (of degree 1) from the tree T'. The resulting graph T" is also a tree consisting of only strong vertices (the number of vertices is 7, the number of edges is 6) According to the condition, each strong vertex is connected to no more than two other strong vertices. Therefore, in T", the degrees of vertices can only equal 1 and 2.

Reasoning similarly to point 2, we conclude that T" has exactly 2 vertices of degree 1 and 5 vertices of degree 2. Now let us consider one of the vertices of degree 1, denoting it a. Let it be connected by an edge to the vertex b1. Let us show that the vertex b1 has degree 2. Indeed, if b1 has degree 1, then none of the other vertices are adjacent to either a or b1.The graph is not connected and, consequently, it is not a tree. Thus, b1 has degree 2. Let b2 denote a neighbor of b1 other than a. Similarly, we conclude that vertex b2 also has degree 2. Next, we conclude that b2 is adjacent to b3 of degree 2, b3 is adjacent to b4 of degree 2, and b4 is adjacent to b5 of degree 2. Since there are no other vertices of degree 2 other than b1, ..., b5, the second neighbor of b5 can only be the second vertex of degree 1 (let c denote it).

So, the tree T" is a chain a, b1, b2, b3, b4, b5, c. The longest path passing through strong vertices is the path between a and c, consisting of edges (a, b1), (b1, b2), (b2, b3), (b3, b4), (b4, b5), (b5, c) and having a length of 6. Any path between two weak vertices in the tree T' passes only through strong vertices. This means that the longest path starts and ends at weak vertices adjacent to a and c, respectively, and has a length greater by 2, i.e. 8.

Evaluation criteria:

Obtaining the correct answer for point 1 is worth 4 points.

Obtaining the correct answer for point 2 earns 5 points.

Obtaining the correct answer for point 1 is worth 5 points.

Computer Science and Information Systems

Task 8
Entry level (2 points)

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Two-digit consecutive binary numbers 00, 01, 10, 11, were used to encode the letters A, B, C, and D, respectively. Which number will represent the sequence DBAC, if the result is provided in hexadecimal notation?

a)   A1
b)   B2
c)   C3
d)   D2

Answer: d

Task 9
Entry level (2 points)

A message was encoded using a variable-length cipher: A – 10, B – 11, C – 100, D – 101. After encoding, the resulting binary cipher was converted to hexadecimal and received: $B72_{16}$. Which of the following is the encrypted message?

a)   DABCA
b)   ADABC
c)   BCADA
d)   DABDA

Answer: a

Task 10
Entry level (2 points)

Binary codes are assigned to five letters of the Latin alphabet, with some letters using two-bit codes and others using three-bit codes. These codes are shown in the table below:

a	b	c	d	e
100	110	011	01	10

Determine which set of letters is encoded with the binary string 1000110110110, if all the letters in the sequence are different.

a)   acdbe
b)   acdeb
c)   cadeb
d)   daceb

Answer: b

Task 11
Entry level (2 points)

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Consider a three-letter alphabet {K, O, T}. How many different five-character-long sequences containing exactly two O's are possible?

a)   70
b)   80
c)   90
d)   100

Answer: b

Task 12
Entry level (2 points)

List all decimal natural numbers not exceeding 17 that end in two identical digits when written in the ternary number system. Provide the numbers in ascending order and separate them with commas.

a)   5, 9, 12, 13, 17
b)   5, 9, 11, 12, 16
c)   4, 8, 9, 13, 17
d)   4, 10, 12, 13, 16

Answer: c

Task 13
Intermediate level (3 points)

An image with dimensions of 128 by 256 pixels requires 24 KB of memory (excluding compression). Determine the maximum number of colors that can be used in the image palette.

a)   32
b)   64
c)   128
d)   256

Answer: b

Task 14
Advanced level (10 points)

There are $\square$ points with integer coordinates on a number line. A grasshopper starts at the leftmost point and needs to reach the rightmost point. It can make jumps of the same length, but must land on one of the specified points with each jump. The grasshopper can make no more than $\square$ jumps. Find the minimum jump length that allows the grasshopper to reach the rightmost point.

Input data format
The first line contains integers n and k ($2 \le n \le 2500$, $1 \le k \le n-1$).

In the next line, n different non-negative integers are given in ascending order, each not exceeding 100,000 (the point coordinates).

Output data format
Calculate a single integer (the answer to the problem).

Example # 1

Standard input	Standard output
5 3 1 2 3 4 5	2

Example #2

Standard Input	Standard Output
9 3 1 3 4 5 7 8 9 10 13	4

Please note that the evaluation will consider your problem-solving process; providing only the final answer is not sufficient.

Solution:
Let us consider all possible jump lengths: the distance from the first point to the second point, the distance from the first point to the third point, and so on. For each jump length, points should be connected, starting from the first point and checking whether a point exists at the position equal to the sum of the coordinate of the current point and the length of the jump. If such a point does not exist, it is impossible to get to the rightmost point; otherwise we should move to the point whose existence is established. If it is possible to reach the rightmost point in this way, covering no more than k segments, the jump length in question is the answer.

Answer:
Below is a solution in the Python3 language

```python
A = input().split()
n = int(A[0])
k = int(A[1])
x = input().split()
for i in range(n):
    x[i] = int(x[i])

for i in range(1, n):
    len = int(x[i]) - int(x[0])
    cnt = 0
    now = x[0]
    #We try to consistently reach the end with such jumps
    while (now != x[n - 1]):
        now += len
        if now not in x:
            cnt = -1
```

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```
      break
   cnt = cnt + 1
   #If the answer is found at any step, we interrupt the loop.
   if cnt != -1 and cnt <= k:
      print(len)
      break
```

Evaluation criteria:
A syntactically correct program is worth 2 points.
A program implementing a suboptimal (slow) algorithm earn 4 points.
A program implementing an optimal (fast) algorithm earns 4 points.

Computer Science and Artificial Intelligence

Task 15
Entry level (1 point)

Which function is used in Python to convert a string or tuple to a list?
a)   zip()
b)   map()
c)   sum()
d)   list()

Response: d

Task 16
Intermediate level (3 points)

Determine the output of the following Python program:

```
string = "Cossack treasure boar pose awl treasure pose retelling awl carp pose treasure"
keyword = "sure"

found_words = []
for word in string.split():
   if not keyword in word:
      found_words.append(word)
count = [0] * len(found_words)
i = 0
res = []
for word1 in found_words:
   for word2 in found_words:
      if word1 == word2:
         count[i] = count[i] + 1
         if count[i] > 2:
            if not word1 in res:
               res.append(word1)
   i = i + 1
```

print(res)

a) **pose**
b)   treasure
c)   awl
d)   Cossack

Answer: a

Task 17
Intermediate level (3 points)

A function describing the operation of a single-layer neural network is written in Python:

```python
def simple_perceptron(input_data : list) -> float:
    if len(input_data) > 2:
        raise Exception("Invalid input data length!")
    weight = [0.5, 0.2]
    result = 0.0
    for x, w in zip (input_data, weight):
        result = result + x * w
    result = result - 0.4
    if result > 0:
        return 1
    else:
        return 0
```

Choose the correct inputs and outputs for this function:
a) **Inputs: 1) [0, 0] 2) [1, 1] Outputs: 1) 0; 2) 1;**
b)   Inputs: 1) [0, 0] 2) [0, 1] Outputs: 1) 0; 2) 1;
c) **Inputs: 1) [0, 0] 2) [1, 0] Outputs: 1) 0; 2) 1;**
d)   Inputs: 1) [0, 0] 2) [1, 1, 1] Outputs: 1) 0; 2) 1;

Answer: a, c

Task 18
Intermediate level (3 points)

A Python function calculates the standard deviation for each of two features within each of two classes ('A' and 'B').

```python
X = [[-1, -1], [-2, -2], [1, 1], [2, 2]] #
y = ['A', 'A', 'B', 'B']

classes = ['A','B']
cls_counts = [2, 2]
n_classes = 2
priors = [c_i / len(y) for c_i in cls_counts]
```

```
sum_class_a = [0]*2
sum_class_b = [0]*2
for x_i, y_i, i in zip(X,y, range(len(y))):
    if y_i == 'A':
        sum_class_a[0] = sum_class_a[0] + x_i[0]
        sum_class_a[1] = sum_class_a[1] + x_i[1]
    else:
        sum_class_b[0] = sum_class_b[0] + x_i[0]
        sum_class_b[1] = sum_class_b[1] + x_i[1]

X_cls_mean = []
X_cls_mean.append([s / cls_counts[0] for s in sum_class_a])
X_cls_mean.append([s / cls_counts[1] for s in sum_class_b])
print("X_cls_mean",X_cls_mean)

sum2_class_a = [0]*2
sum2_class_b = [0]*2
for x_i, y_i, i in zip(X,y, range(len(y))):
    if y_i == 'A':
        sum2_class_a[0] = sum2_class_a[0] + (x_i[0] - X_cls_mean[0][0])**2
        sum2_class_a[1] = sum2_class_a[1] + (x_i[1] - X_cls_mean[0][1])**2
    else:
        sum2_class_b[0] = sum2_class_b[0] + (x_i[0] - X_cls_mean[1][0])**2
        sum2_class_b[1] = sum2_class_b[1] + (x_i[1] - X_cls_mean[1][1])**2

X_stds = []
X_stds.append([(s / cls_counts[0]) ** 0.5 for s in sum2_class_a])
X_stds.append([(s / cls_counts[1]) ** 0.5 for s in sum2_class_b])

print("X_stds",X_stds)
```

Which of the statements are correct?
a)   X_stds[0] = [0.7071067811865476, 0.7071067811865476]
b)   **X_stds[1] =[0.5, 0.5].**
c)   **X_stds[0] =[0.5, 0.5].**
d)   X_stds[1] =[0.7071067811865476, 0.7071067811865476].

Answer: b, c

Interdisciplinary Applications of Computer Science

Task 19
Entry level (1 point)

Vasya is creating 5-letter words using the letters A, B, C, and D, with the constraint that the letter A must appear exactly once. The other letters (B, C, D) can appear any number of times or not at

all. A word is any valid sequence of letters, not necessarily meaningful. Determine the number of such possible words.

a)   230
b)   118
c)   225
d)   405

Answer: d

Task 20
Entry level (2 points)

Olga is creating a table of code words for transmitting messages, each message having its own code word. She uses as code words 4-letter words that contain only the letters A, B, C, D, X, and Y. The first letter of a code word must be X or Y, and neither of these two letters can appear in any other position in the code word. How many different code words can Olga use?

a)   192
b)   128
c)   256
d)   214

Answer: b

Task 21
Entry level (1 point)

What is the minimum amount of storage (in KB) required to save a 128×128 pixel bitmap image that can use 256 different colors?

a)   10
b)   16
c)   128
d)   64

Answer: b

Task 22
Intermediate level (3 points)

After converting a bitmap image file, its size was reduced by half. Determine the maximum number of colors that could have been in the original palette, given that the converted bitmap image, which has the same resolution, uses a 16-color palette.

a)   64
b)   128
c)   256

d)   512

Answer: c

Computer Science and Software Engineering

Task 23
Entry level (1 point)

Which is the correct order of use for software development tools?

a)   linker; debugger; compiler; editor; profiler
b)   editor; compiler; linker; debugger; profiler
c)   profiler; linker; debugger; compiler; editor;
d)   editor; linker; compiler; debugger; profiler

Answer: b

Task 24
Entry level (1 point)

Arrange the following Git commands in the correct order for performing a typical update of a program code on the server:

a)   git push; git add; git commit;
b)   git commit; git push; git add;
c)   git add; git commit; git push;

Answer: c

Task 25
Intermediate level (3 points)

Which of the following is the lowest base of a number system, where the number 50 is written in two digits?
a)   2
b)   6
c)   8
d)   10

Answer: c

Task 26
Intermediate level (3 points)

An automatic camera takes bitmap images with a resolution of 640 × 480 pixels. The size of an image file cannot exceed 320 KB, and the data is uncompressed. What is the maximum number of colors that can be used in the palette?

a) 32
b) 16
c) 128
d) 256

Response: d

Task 27
Advanced level (10 points)

A k-nearest neighbors algorithm assigns an object to the class that most of its k nearest neighbors belong to. Uncertainty is considered an error. Write a k-nearest neighbors algorithm for points on a plane, assuming that $\square$ is an odd number and there are only two classes, labeled 0 and 1.

Input data format
In the first line, an integer is the number of points for which a class value is given.
In the second line, an integer is the number of neighbors.
In the third line, two integers represent the coordinates of the point whose class is to be defined.
In each subsequent line, there are three integers: the first two are the coordinates of the object, and the third is the class number.

Output data format
A number: the number of the class to which the algorithm has assigned the object (the number 0 or 1).

Example # 1

Standard Input	Standard Output
4 1 1 1 1 2 0 2 5 0 4 8 1 1 5 0	0

Please note that the evaluation will consider your problem-solving process; providing only the final answer is not sufficient.

Solution:
For the point you want to classify, measure all the distances to other points. Select k points with the smallest distances. Indicate the class to which most of the selected k points belong.

Answer:
Below is a solution in the Python3 language

```
n = int(input())
k = int(input())
```

```
x0, y0 = map(int, input().split())

coordinates = []
class_labels = []
for i in range(n):
    x, y, point_class = map(int, input().split())
    class_labels.append(point_class)
    coordinates.append([x,y])

def distance(x1, x2):
    return ((x1[0]-x2[0])**2 + (x1[1]-x2[1])**2)**(0.5)

nearest_neighbors = []
neighbors_distances = []
neighbors_classes = []

for i in range(k):
    nearest_neighbors.append(coordinates[j])
    neighbors_distances.append(distance([x0, y0], coordinates[i]))
    neighbors_classes.append(class_labels[i])

'''
Searching for k nearest neighbors.
'''
for i in range(k, n):
    for j in range(k):
        if distance([x0, y0], coordinates[i]) < neighbors_distances[j]:
            neighbors_distances[j] = distance([x0, y0], coordinates[i])
            nearest_neighbors[j] = coordinates[i]
            neighbors_classes[j] = class_labels[i]

point_class = 0
if neighbors_classes.count(1) > neighbors_classes.count(0):
    point_class = 1
print(point_class)
```

Evaluation criteria:
A syntactically correct program earns 2 points.
A program implementing a suboptimal (slow) algorithm earns 4 points.
A program implementing the optimal (fast) algorithm is worth 4 points.

Computer Science, Hardware, and Architecture

Task 28
Entry level (1 point)

Which of the following methods is used for long-term storage of user information?
a) **external storage devices**

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b)   catalogs and libraries
c)   processors
d)   floppy disks
e)   random access memory

Answer: e

Task 29
Entry level (1 point)

Which device is shown in the picture?

a)   processor
b)   solid state drive
c)   **random access memory**
d)   network card
e)   video card

Answer: c

Task 30
Entry level (1 point)

Which of the following is NOT a part of the microprocessor?
a)   access Point Management Module (OSDP)
b)   arithmetic logic unit (ALU)
c)   control unit (CU)
d)   **read-only memory (ROM)**

Answer: d

Task 31
Intermediate level (3 points)

Which of the following represents the number 26586 in the hexadecimal system?
a)   67AD
b)   673F
c)   65AC
d)   **67DA**
e)   642D
f)   66411

Answer: d

Telecommunications

Task 32
Entry level (1 point)

To encode a message consisting only of the letters A, B, C, D, and E, a non-uniform binary code is used:

A	B	C	D	E
000	11	01	001	10

Which (only one!) of the four received messages was transmitted without errors and can be decoded (specify the message number):

a) **110000010011110**
b)   110000011011110
c)   110001001001110
d)   110000001011110

Answer: a

Task 33
Entry level (1 point)

To encode a message consisting of the letters X, W, Y, and Z, the following two-digit binary numbers were used: 00 for X, 01 for W, 10 for Y, and 11 for Z. What will one obtain by encoding the character sequence YXZXWX in this way and writing the result in the hexadecimal code?

a) **434**
b)   4B8
c)   8B4
d)   8X4

Answer: a

Task 34
Entry level (1 point)

To encode the letters K, L, M, and N, four-digit consecutive binary numbers from 1000 to 1011, respectively, were used. What will one obtain by encoding the KMLN characters in this way and writing the result in octal code?

a) 84613_8
b)   **105233_8**
c) 12345_8
d) 776325_8

Answer: b

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Task 35
Intermediate level (3 points)

How many seconds does it take a modem sending messages at 14400 bps to transmit a 640×480 pixel color bitmap image, assuming that the color of each pixel is encoded in 24 bits?

a)   64
b)   128
c)   256
d)   512

Answer: d