

Computer Science

Instructions for examinee

א. Duration of exam: Three hours.

ב. Exam structure and breakdown of points:

This exam has three parts.

Part One – This part has three questions. Answer them according to the directions in this part of the exam.
 $(1 \times 10) + (1 \times 15) = 25$ points

Part Two – This part has three questions. Answer two of them.
 $(2 \times 25) = 50$ points

Part Three – This part has questions in four different tracks.
Answer one question for the track in which you studied.

$(1 \times 25) = 25$ points
Total – 100 points

ג. Material that may be used during the exam:

All material, except for a programmable computer.

ד. Special instructions:

- (1) For all of the programs you are required to write in Parts One and Two, use only one language – Java or C#.
- (2) **On the outer cover** of the answer booklet, write which **language** you are using – Java or C#.
- (3) **On the outer cover** of the answer booklet, write the name of the **track which you studied**, one of these four tracks:
Computer Systems and Assembly Language,
Introduction to Operations Research,
Computational Models,
Object-Oriented Programming.

Note: In the programs you write, you will not lose points for writing upper-case letters instead of lower-case letters or vice-versa.

Write only in the answer booklet. Use separate pages for everything you want to use as draft material (outlines, calculations, etc.). Write "טיוטה" at the top of each draft page. Writing drafts on pages outside the answer booklet may lead to the disqualification of the exam!

Good Luck!

מדעי המחשב

הוראות לנבחן

א. משך הבחינה: שלוש שעות.

ב. מבנה השאלון ומפתח ההערכה:

בשאלון זה שלושה פרקים.

פרק ראשון – בפרק זה שלוש שאלות, ענה על פי ההוראות בפרק.

$(10 \times 1) + (15 \times 1) = 25$ נקודות

פרק שני – בפרק זה יש שלוש שאלות, ומהן עליך לענות על שתיים.

$(25 \times 2) = 50$ נקודות

פרק שלישי – בפרק זה שאלות בארבע מסלולים שונים.

ענה על שאלה אחת במסלול שלמדת.

$(25 \times 1) = 25$ נקודות

סה"כ – 100 נקודות

ג. חומר עזר מותר בשימוש:

כל חומר עזר, חוץ ממחשב הניתן לתכנות.

ד. הוראות מיוחדות:

(1) את כל התכניות שאתה נדרש לכתוב בשפת מחשב

בפרקים הראשון והשני, כתוב בשפה אחת בלבד – Java או C#.

(2) **רשום על הכריכה החיצונית** של המחברת באיזו שפה אתה כותב –

Java או C#.

(3) **רשום על הכריכה החיצונית** של המחברת את שם **המסלול שלמדת**.

המסלול הוא אחד מארבעת המסלולים האלה:

מערכות מחשב ואסמבלי, מבוא לחקר ביצועים,

מודלים חישוביים, תכנות מונחה עצמים.

הערה: בתכניות שאתה כותב לא יורדו לך נקודות,

אם תכתוב אות גדולה במקום אות קטנה או להפך.

כתוב במחברת הבחינה בלבד, בעמודים נפרדים, כל מה שברצונך לכתוב

כטיוטה (ראשי פרקים, חישובים וכדומה).

רשום "טיוטה" בראש כל עמוד טיוטה.

רישום טיוטות כלשהן על דפים מחוץ למחברת הבחינה עלול לגרום

לפסילת הבחינה!

בהצלחה!

Questions

This exam has three parts.

You must answer questions from all three parts, according to the directions in each part.

Part One (25 points)

Note: For each question that requires input, there is no need to check the validity of the input.

For those working in Java: For each question that requires input, assume that the program contains the instruction:

Scanner input = new Scanner (System.in);

Answer Question 1 — Required (10 points).

1. Given: the class **AllNumbers**, which has one attribute (property) [תכונה]:

arrayNum – a one-dimensional array of integers.

The array contains positive numbers larger than zero, which may be even or odd.

Write an internal method [פעולה פנימית] lastOddValue in Java or LastOddValue in C# that returns the value of the last odd number in the array.

For example, for the array arrayNum of size 6 shown below, the method should return the number 3, which is the value of the last odd number in the array.

	0	1	2	3	4	5
arrayNum	7	5	8	9	3	4

Assume that there is at least one odd number in the array.

Answer one of the questions 2-3 (15 points).

2. 40 songs numbered from 1 to 40 compete in the hit parade. 25 judges rank the songs.

Each judge chooses the three songs that, in his opinion, are the best. The judge's first-place (best) song gets 7 points, his second-place song gets 5 points, and his third-place song gets 1 point.

The song that gets the highest total number of points from all the judges wins first place in the hit parade.

In preparation for the hit parade, a class **Vote** was defined.

The class has three attributes:

- first – the number of the song that the judge ranked in first place, of type integer.
- second – the number of the song that the judge ranked in second place, of type integer.
- third – the number of the song that the judge ranked in third place, of type integer.

Assume that for each attribute, `get` and `set` methods have been defined in Java, and `Get` and `Set` methods in C#.

Write an external method [פעולה חיצונית] `theWinner` in Java or `TheWinner` in C# that receives an array of type **Vote** of rankings by the judges, and prints the number of the song that wins first place.

Assume that only one song wins.

Assume that the values of the array are valid.

3. Given: class **Time**, which has two attributes:

- hour – represents an hour between 0 and 23 inclusive, of type integer.
- minute – represents a minute between 0 and 59 inclusive, of type integer.

Assume that for each attribute, `get` and `set` methods have been defined in Java, and `Get` and `Set` methods in C#.

- א. Write in Java or in C# a constructor in class **Time** that receives values for **every** attribute. For each attribute, if the value received is not possible according to the definition of the attribute, it should be replaced by 0.

ב. Given: class **Flight**, which has four attributes:

- name – name of airline, of type string,
- destination – name of destination country, of type string,
- flightCode – flight code, of type string,
- flightTime – flight time, of type **Time**.

Write in Java or C# the class header and the class attributes.

ג. Given: class **Airport**, which has one attribute:

- flights – a one-dimensional array of type **Flight**.

Assume that for each attribute in class **Flight**, `get` and `set` methods have been defined in Java, and `Get` and `Set` methods in C#.

Class **Airport** contains a boolean internal method `isFly` in Java and `IsFly` in C#, whose purpose is to check whether a flight of the airline "Sky" appears in the array `flights`.

The method returns `true` if the array `flights` contains a flight of the airline "Sky".

Otherwise, the method returns `false`.

Assume that all the elements of the array are different from `null`.

The following method (`isFly` in Java and `IsFly` in C#) is **incorrect**.

<u>Java</u>	<u>C#</u>
<pre>public boolean isFly() { for (int i = 0; i < this.flights.length; i++) { if (this.flights[i].getName().equals ("Sky")) return true; return false; } }</pre>	<pre>public bool IsFly() { for (int i = 0; i < this.flights.Length; i++) { if (this.flights[i].GetName() == "Sky") return true; return false; } }</pre>

(Note: the sub-items of Item ג appear on the next page.)

/Continued on page 5/

- (1) Write down what the given **incorrect** method will return for an array `flights` of size 4, whose `name` attribute values of the objects in the array are:
in the first element: "Cloud",
in the second element: "Air",
in the third element: "Sky",
in the fourth element: "Travel".
- (2) Explain what the error in the method is.
- (3) Correct the method so that it will perform what is required, and copy the corrected method to your answer booklet.

Part Two (50 points)

Note: For each question that requires implementation, you may use the methods of the classes: queue, stack, binary tree, and link, without implementing them. If you use any additional methods, you must implement them.

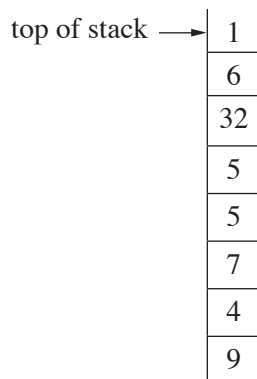
Answer two of the questions 4-6 (each question — 25 points).

4. ✖. Write an external method `lastAndRemove` in Java or `LastAndRemove` in C# that receives a stack of type integer, deletes the element at the bottom of the stack, and returns its value.

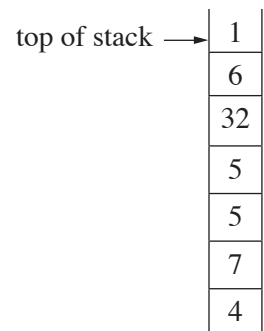
At the end of the method execution, the other elements in the stack remain unchanged.

Assume that the stack is not empty.

For example, for
the following stack:



At the end of the method, the value 9 will be
returned, and the stack will appear like this:



(Note: Item 2 appears on the next page.)

2. Given the class:

TwoItems	
Attributes:	int num1 int num2
Constructor:	TwoItems (int number1, int number2)

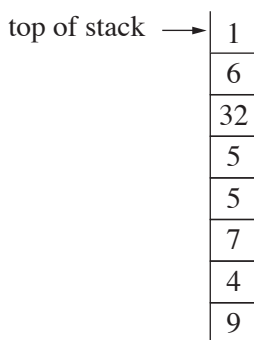
Assume that for each attribute, get and set methods have been defined in Java, and Get and Set methods in C#.

Write an external method `stackTwoItems` in Java or `StackTwoItems` in C# that receives a nonempty stack `stk1` of type integer, of an even size, and returns a stack of type `TwoItems`.

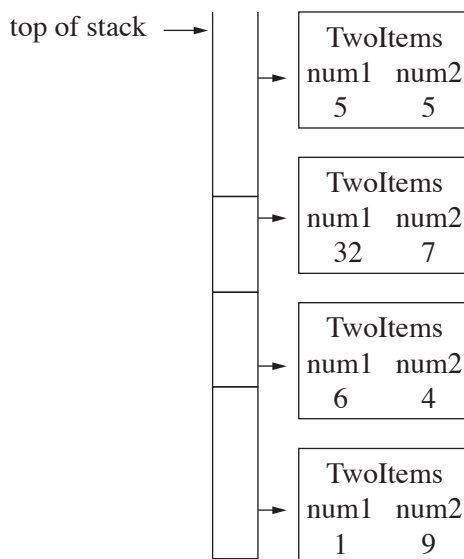
The element at the bottom of the returned stack will contain a reference to an instance of `TwoItems` whose attribute `num1` is the element at the top of stack `stk1`, and whose attribute `num2` is the element at the bottom of stack `stk1`.

The element above the bottom element in the returned stack will contain a reference to an instance of `TwoItems` whose attribute `num1` is the element below the top element of stack `stk1`, and whose attribute `num2` is the element above the bottom element of stack `stk1`, and so on, such that the element at the top of the returned stack will contain a reference to an instance of `TwoItems` whose attributes `num1` and `num2` are two adjacent elements located in the middle of stack `stk1`.

For example, for the following stack `stk1`:



After the method, the following stack will be returned:



You must use the method you wrote in Item 1.

Note: You do not need to preserve the original content of stack `stk1`.

5. Note: This question has a Java version on page 8, and a C# version on page 9.

For those using Java

Given: the method sod1:

```
public static Node <Character> sod1(Node <Character> lst, char ch)
{
    if (lst == null)
        return null;
    if (lst.getValue() == ch)
        return lst;
    return sod1(lst.getNext(), ch);
}
```

- א. (1) Trace the method and write down what will be returned for `ch = 'v'` and the reference `lst` to the linked list of characters:



- (2) What is the purpose of method `sod1` ?
(3) What is the run-time complexity of method `sod1` ? Explain.

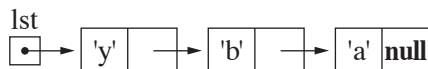
- ב. Given: the method `sod2` :

```
public static boolean sod2(Node <Character> lst)
{
    if (sod1(lst,'a') != null && sod1(lst,'b') != null)
        return true;
    return false;
}
```

What is the purpose of method `sod2` ?

- ג. Write a boolean method that receives a reference to a linked list of characters and returns `true` if it contains two adjacent nodes whose values are 'a' 'b' or 'b' 'a'. Otherwise, the method returns `false`.

Examples of linked lists in which 'b' 'a' or 'a' 'b' appear consecutively:



Example of a linked list in which 'a' 'b' and 'b' 'a' do not appear consecutively:



Use method `sod1`.

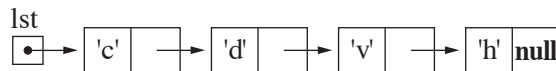
Assume that all the characters are different from each other.

For those using C#

Given: the method Sod1:

```
public static Node <char> Sod1(Node <char> lst, char ch)
{
    if (lst == null)
        return null;
    if (lst.GetValue() == ch)
        return lst;
    return Sod1(lst.GetNext(), ch);
}
```

8. (1) Trace the method and write down what will be returned for $ch = 'v'$ and the reference lst to the linked list of characters:



- (2) What is the purpose of method Sod1 ?
(3) What is the run-time complexity of method Sod1 ? Explain.

9. Given: the method Sod2 :

```
public static bool Sod2(Node <char> lst)
{
    if (Sod1(lst,'a') != null && Sod1(lst,'b') != null)
        return true;
    return false;
}
```

What is the purpose of method Sod2 ?

10. Write a boolean method that receives a reference to a linked list of characters and returns true if it contains two adjacent nodes whose values are 'a' 'b' or 'b' 'a'. Otherwise, the method returns false.

Examples of linked lists in which 'b' 'a' or 'a' 'b' appear consecutively:



Example of a linked list in which 'a' 'b' and 'b' 'a' do not appear consecutively:



Use method Sod1.

Assume that all the characters are different from each other.

6. Given: the method:

In Java:

```
public static boolean lessThanTree (BinNode <Integer> t, int x)
```

In C#:

```
public static bool LessThanTree (BinNode <int> t, int x)
```

The method returns `true` if `x` is smaller than all the values in the tree `t`.

Otherwise, the method returns `false`.

The run-time complexity of the method is $O(n)$. n represents the number of nodes in the tree `t`.

א. Write an external method `treeLessThanTree` in Java or `TreeLessThanTree` in C#, which receives two binary trees `t1` and `t2` of integer values. It is given that `t2` contains at least one node. The method returns `true` if every value in the tree `t1` is smaller than each of the values in the tree `t2`. Otherwise, the method returns `false`.

If `t1` is `null`, the method returns `true`.

You may use the given method `lessThanTree` or `LessThanTree` without implementing it.

If you use other methods, you must implement them.

ב. What is the run-time complexity of the method you wrote in Item א? Explain.

Part Three (25 points)

Part Three includes questions in four tracks:

Computer Systems and Assembly Language, pages 11-13.

Introduction to Operations Research, pages 14-17.

Computational Models, pages 18-19.

Object-Oriented Programming in Java, pages 20-23;

Object-Oriented Programming in C#, pages 24-27.

Answer one question for the track that you studied.

Computer Systems and Assembly Language

If you studied this track, answer one of the questions 7-8 (25 points).

7. This question includes two unrelated items, א and ב. Answer both of them.

א. Shown below is an Assembly program fragment.

Assume that the numbers are unsigned.

```
CMP AH, AL
JAE AA
XCHG AH, AL
AA:  CMP AL, AH
     JAE CC
     INC AL
     DEC AH
     JMP AA
CC:  MOV SI, 100H
     MOV [SI], AL
```

- (1) Register AX contains 0109H. Trace the execution of the program fragment using a trace table, and write down what the memory cell whose address is 100H will contain after the fragment's execution.
- (2) What does the program fragment do for odd numbers in registers AH, AL?
In your answer, relate also to the contents of registers AH, AL before execution of the program fragment.

ב. (Unrelated to Item א.)

Determine whether each of the six statements below is true or false.

If the statement is false, explain why.

- (1) The two fragments 1 and 2 below do the same thing.

Fragment 1

SHL AX, 1

SHR AX, 1

Fragment 2

SHR AX, 1

SHL AX, 1

- (2) The two fragments 1 and 2 below do the same thing.

Fragment 1

AND AX, 0FEh

Fragment 2

SHR AX, 1

SHL AX, 1

- (3) The two fragments 1 and 2 below do the same thing.

Fragment 1

PUSH AX

PUSH BX

POP AX

POP BX

Fragment 2

XCHG AX, BX

- (4) The two fragments 1 and 2 below do the same thing.

Fragment 1

SUB AX, 0

JNE A1

Fragment 2

CMP AX, 0

JNZ A1

- (5) An array was defined in the data segment:

ARR DW 50 dup (?)

Assume that the address of a certain element in array ARR is stored in register BX.

This program fragment stores the index of that element in register BX.

LEA SI, ARR

SUB BX, SI

INC BX

- (6) The value of the number 11101011 that is stored in 2's-complement form in 8 bits is (-21) in base 10.

8. The following data were defined in the data segment:

ARR DB 100 DUP (?)

REZ DB ?

Assume that the numbers are signed.

Assume that all the numbers in the array are different from each other.

An array is called "wavy" ["גלי"] if it fulfills these conditions:

The first element is smaller than the second element, the second element is larger than the third element, the third element is smaller than the fourth element, the fourth element is larger than the fifth element, and so on.

Example of a "wavy" array:

0	1	2	3	4
-2	8	6	17	-7

Explanation of the example: The first element (-2) is smaller than the second element (8), the second element (8) is larger than the third element (6), the third element (6) is smaller than the fourth element (17), and the fourth element (17) is larger than the fifth element (-7).

Write a program fragment that checks whether the array ARR is a "wavy" array. If so, assign the value 1 to the variable REZ. Otherwise, assign the value 0 to the variable REZ.

Introduction to Operations Research

If you studied this track, answer one of the questions 9-10 (25 points).

9. Given: a linear programming problem

$$\max \{z = 4x_1 + 6x_2\}$$

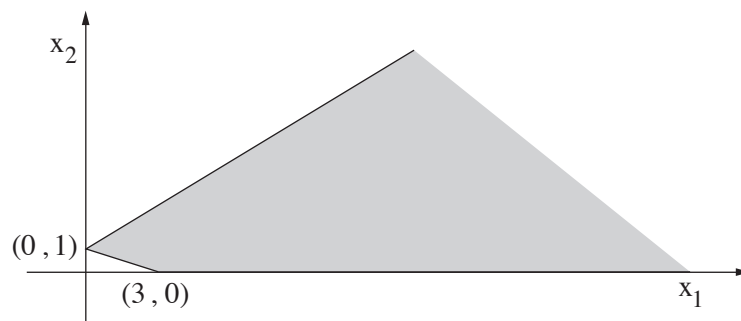
subject to these constraints:

$$(1) \quad -5x_1 + 4x_2 \leq 4$$

$$(2) \quad x_1 + 3x_2 \geq 3$$

$$(3) \quad x_2 \geq 0$$

A sketch of the range of possible solutions to the given problem is shown below.



Each of the items 1-4 on the next page refers to the given linear programming problem.

The items 1-4 are unrelated to each other. Answer all of the items.

Four statements, i-iv, are given. For each of the items 1-4 on the next page, only one statement is correct.

- i There is only a single optimal solution.
- ii There is an infinite number of optimal solutions.
- iii The optimal solution is unbounded [לא חסום].
- iv There is no optimal solution.

For each of the items א-ו, determine which of the statements i-iv is correct.

Specify the item, copy the correct statement into your answer booklet and explain your answer.

- If you chose Statement i for any item, find the single optimal solution and the value of the objective function for this solution.
- If you chose Statement ii for any item, write down the general optimal solution to the problem and the value of the objective function within the range of optimal solutions.

א. Which statement is true for the linear programming problem given at the beginning of the question? Explain your answer.

ב. We change only the objective function of the problem given at the beginning of the question to $\min \{z = 4x_1 + 6x_2\}$.
After changing the objective function, which statement is true? Explain your answer.

ג. We change only the objective function of the problem given at the beginning of the question to $\max \{z = 2x_1 + 6x_2\}$.
After changing the objective function, which statement is true? Explain your answer.

ד. We change only the objective function of the problem given at the beginning of the question to $\min \{z = 2x_1 + 6x_2\}$.
After changing the objective function, which statement is true? Explain your answer.

ה. We add an additional constraint to the problem given at the beginning of the question: $x_1 + x_2 \leq 1$. Which statement is true after addition of this constraint? Explain your answer.

ו. We add an additional constraint to the problem given at the beginning of the question: $x_2 \leq -x_1$. Which statement is true after addition of this constraint? Explain your answer.

10. This question has two unrelated items, א and ב. Answer both of them.

א. $G = (V, E)$ is a **directed** graph represented by the following adjacency matrix.

$$\begin{matrix} & \begin{matrix} \mathbf{a} & \mathbf{b} & \mathbf{c} & \mathbf{d} & \mathbf{e} \end{matrix} \\ \begin{matrix} \mathbf{a} \\ \mathbf{b} \\ \mathbf{c} \\ \mathbf{d} \\ \mathbf{e} \end{matrix} & \begin{bmatrix} 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} \end{matrix}$$

- (1) Sketch the graph G that is represented by the adjacency matrix.
- (2) Find the strongly connected components [רכיבי הקשירות החזקה – רק"חים] in the given graph. For each strongly connected component that you find, list its set of vertices.
- (3) Determine the maximum number of edges that can be removed from the given graph, and the graph will still contain the same number of strongly connected components that you found in Sub-item א(2). What is/are the edge(s)?

ב. (Unrelated to Item א.)

(1) The table below shows a transport problem and part of a possible basic solution:

$$x_{11} = 9, \quad x_{12} = 1.$$

Origins	Destinations			Supply
	1	2	3	
1	1 9	5 1	7	10
2	1	8	4	11
3	5	2	8	10
Demand	9	12	10	

Copy the table into your answer booklet and then fill in the values using the northwest corner method.

- (2) The table below shows part of a possible basic solution to a transport problem and values of $u_1, u_2, u_3, v_1, v_2, v_3$.

Origins	Destinations			Supply	u_i
	1	2	3		
1	3 20	5	7	20	1
2	2	8 10	14	10	0
3	2	6	8 10	15	-2
Demand	20	15	10		
v_j	2	8	10		

Copy the table into your answer booklet and then complete it, taking into account the values of all the u_i 's and v_j 's, such that a possible basic solution will be obtained.

- (3) The table below shows a possible basic solution to a transport problem and values of $u_1, u_2, u_3, v_1, v_2, v_3$.

Origins	Destinations			Supply	u_i
	1	2	3		
1	34 15	15 15	17 3	18	0
2	10 10	8 0	4	10	-7
3	25	18	18 10	10	1
Demand	10	15	13		
v_j	17	15	17		

Is the solution optimal? Explain your answer.

Computational Models

If you studied this track, answer one of the questions 11-12 (25 points).

11. This question has two unrelated items, א and ב. Answer both of them.

- א. Definition: A **prefix** of a word x is any word that is obtained by removing any number of characters from the end of the word x , including the empty word and the word x itself.

For example: For the word $x = \text{abcbad}$, all the prefixes of the word x are:

$\varepsilon, a, ab, abc, abcb, abcba, abcbad$

L is a language over the alphabet $\Sigma = \{a, b, c, d\}$.

L is the set of words in which, for **every prefix** of the word, the difference between the number of times the character c appears and the number of times the character d appears is greater than or equal to 0 and less than or equal to 3:

$$0 \leq \#_c(w) - \#_d(w) \leq 3, \text{ where}$$

$\#_c(w)$ is the number of appearances of c in the prefix word w .

$\#_d(w)$ is the number of appearances of d in the prefix word w .

Examples of words that belong to the language L :

accbdcacab , bacaabdbcb , abba , cdcdcd , abcbadb

Examples of words that do not belong to the language L :

daac — because there is the prefix d , for which $\#_c(w) - \#_d(w) = -1 < 0$

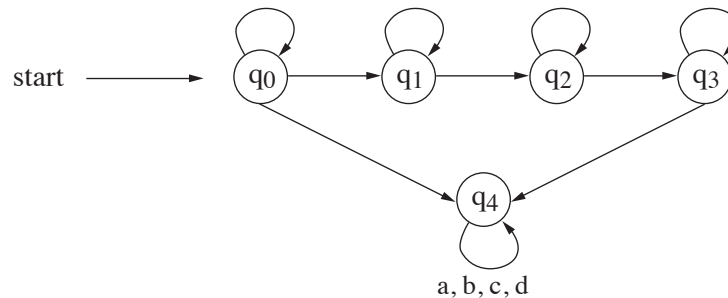
cddc — because there is the prefix cdd , for which $\#_c(w) - \#_d(w) = -1 < 0$

accbdcacacd — because there is the prefix accbdcacac , for which $\#_c(w) - \#_d(w) = 4 > 3$

(Note: The question continues on the next page.)

Shown below is a partial diagram of a **deterministic** finite automaton that accepts the language L. The diagram is missing transitions, input symbols, and accept states.

The diagram contains all the states of the automaton.



Copy the diagram to your answer booklet, and complete it so that the automaton will be **deterministic** and will accept the language L.

Fill in the missing transitions and the missing input symbols, and mark **all the accept states**.

Note: Do not add states to the automaton, and do not delete states or transitions from it.

ב. (Unrelated to Item א.)

Σ^* is the set of all words over the alphabet Σ , including the empty word.

Given: two languages L_1 , L_2 over the alphabet Σ .

$L_1 = \Sigma^*$. L_2 is a non-regular language.

We define: $L_3 = L_2 \cap \bar{L}_1$.

(1) What is the language $\bar{L}_1$?

(2) Is the language L_3 regular? Explain your answer.

12. This question has two unrelated items, א and ב. Answer both of them.

א. Given: the alphabet $\Sigma = \{a, b\}$. Build a pushdown automaton [אוטומט מחסנית] for the language:

$$L = \{a^2 b^k a^n \mid n > 0, k > 0, n < k\}$$

ב. (Unrelated to Item א.)

Build a Turing machine that accepts as input a number x in unary representation, and calculates the value of the following function:

$$f(x) = \begin{cases} x + 1 & x < 2 \\ x - 1 & x \geq 2 \end{cases}$$

Object-Oriented Programming

If you studied this track and are working in Java, answer one of the questions 13-14. (25 points)

13. Below is a project in which these classes have been defined: A, B, C, D, E. The method `f()` has been implemented in two classes in the project. The following code fragment is **valid**.

```
A a1 = new A();  
A e1 = new E();  
E c1 = new C();  
C b1 = new B();  
C d1 = new D();
```

Given:

The instruction `B d2 = new D();` causes a compilation error.

The instruction `a1.f();` causes a compilation error.

The instruction `((E)e1).f();` is valid and prints "bye-bye".

The instruction `((B)b1).f();` is valid and prints "hello".

The instruction `((D)b1).f();` causes a run-time error.

- א. Draw an inheritance tree of all the classes, and indicate in which two classes the method `f()` has been implemented.

- ב. Given: the class Z:

```
public class Z  
{  
    public void g(){}  
}
```

- (1) Add class Z to the inheritance tree that you drew in Item א, such that the following instruction will be valid:

```
Z x = new A();
```

- (2) The following code fragment is **valid**.

```
A a2 = new A();  
Z z1 = new Z();  
Z a3 = new A();
```

For each of the following instructions, i-v, state whether it is valid or invalid.

If the instruction is invalid, explain why. The items i-v are **unrelated** to each other.

- i `a2 = z1;`
- ii `a3 = z1;`
- iii `((A)z1).g();`
- iv `a2.g();`
- v `((A)a3).g();`

ג. Given class Y:

```
public class Y
{
    public void m(){}
}
```

(1) Add class Y to the inheritance tree that you drew in Item א, such that the following instruction will be valid (disregard the data in Item ב).

```
C f = new Y ();
```

(2) The following code fragment is **valid**.

```
A a2 = new A();
```

```
Y y1 = new Y();
```

```
C y2 = new Y();
```

For each of the following instructions, i-v, state whether it is valid or invalid.

If the instruction is invalid, explain why. The items i-v are **unrelated** to each other.

i a2 = y1;

ii y2 = y1;

iii ((A)y1).m();

iv y2.m();

v ((A)y2).m();

14. Property tax is a payment to the local authorities for the area of the dwellings and additional land owned by residents. The rate of property tax is 10 shekels/sq. meter for residential space and 0.5 shekels/sq. meter for additional land. For example, a resident who owns a dwelling with an area of 100 sq. meters and additional land of 500 sq. meters pays a total property tax of $100 \cdot 10 + 500 \cdot 0.5 = 1250$.

Residents were divided into three groups:

- A city resident pays property tax for the dwelling area and other land he owns, and receives a grant of 250 shekels for payment of the property tax.
- A senior city resident – a city resident 60+ years old – pays property tax like a city resident, and in addition is eligible for a discount according to his age: 1% discount for each year of life after age 60. The discount is calculated after deducting the grant from the original sum.
- A village resident pays property tax for the dwelling area and other land he owns and is eligible for a discount of 10%. **A village resident 60+ years old is not eligible for the age-dependent discount.**

If the total property tax to be paid, after deducting the discount and the grant, is a negative number, the resident is exempt from payment (pays 0 shekels).

It was decided to develop software for calculation and collection of property taxes from the residents. For this purpose, the following interface was defined:

interface IData

```
{  
    public String getName(); // returns name of resident  
    public double getPropertyTax(); // returns amount of property tax  
}
```

In Items א and ב below, define the classes in accordance with the principles of object-oriented programming and the following requirements:

- Define only once as constants the data for calculating the property tax (payment for dwelling area per sq. meter, payment for land per sq. meter, rate of discount in percent, amount of grant in shekels).
- Define all the attributes that are not constant as `private`.
- א. Define a class `Resident` (representing a resident), which implements the interface `IData`, and define in it the attributes of the class (you do not need to write a constructor).

(Note: The question continues on the next page.)

- ב. Define three classes, one for each of the following groups of residents:

CityResident, SeniorCityResident, and VillageResident.

For each of the three groups of residents, define the class attributes and write the method `getPropertyTax()` that calculates the property tax (you do not need to write a constructor).

- ג. Given: the body of a method that receives an array `a` of residents' data and prints for each senior city resident his name and the amount of property tax he is required to pay:

```
for (int i = 0; i < a.length; i++)  
{  
    if (a[i] instanceof SeniorCityResident)  
    {  
        System.out.println(a[i].getName()+" "+a[i].getPropertyTax());  
    }  
}
```

For each of the following method headers, (1)-(3), indicate whether the method is valid or invalid. If the method is invalid, explain why, correct the method, and copy the corrected method to your answer booklet.

- (1) `public static void print(Object [] a)`
- (2) `public static void print(IData [] a)`
- (3) `public static void print(Resident [] a)`

Object-Oriented Programming

If you studied this track and are working in C#, answer one of the questions 15-16. (25 points)

15. Below is a project in which these classes have been defined: A, B, C, D, E. The method F() has been implemented in two classes in the project. The following code fragment is **valid**.

```
A a1 = new A();  
A e1 = new E();  
E c1 = new C();  
C b1 = new B();  
C d1 = new D();
```

Given:

The instruction B d2 = new D(); causes a compilation error.

The instruction a1.F(); causes a compilation error.

The instruction ((E)e1).F(); is valid and prints "bye-bye".

The instruction ((B)b1).F(); is valid and prints "hello".

The instruction ((D)b1).F(); causes a run-time error.

א. Draw an inheritance tree of all the classes, and indicate in which two classes the method F() has been implemented.

ב. Given: the class Z:

```
public class Z  
{  
    public void G(){}  
}
```

(1) Add class Z to the inheritance tree that you drew in Item א, such that the following instruction will be valid:

```
Z x = new A();
```

(2) The following code fragment is **valid**.

```
A a2 = new A();  
Z z1 = new Z();  
Z a3 = new A();
```

For each of the following instructions, i-v, state whether it is valid or invalid.

If the instruction is invalid, explain why. The items i-v are **unrelated** to each other.

- i a2 = z1;
- ii a3 = z1;
- iii ((A)z1).G();
- iv a2.G();
- v ((A)a3).G();

ג. Given: class Y:

```
public class Y
{
    public void M(){}
}
```

(1) Add class Y to the inheritance tree that you drew in Item א, such that the following instruction will be valid (disregard the data in Item ב).

```
C f = new Y ();
```

(2) The following code fragment is **valid**.

```
A a2 = new A();
```

```
Y y1 = new Y();
```

```
C y2 = new Y();
```

For each of the following instructions, i-v, state whether it is valid or invalid.

If the instruction is invalid, explain why. The items i-v are **unrelated** to each other.

i a2 = y1;

ii y2 = y1;

iii ((A)y1).M();

iv y2.M();

v ((A)y2).M();

16. Property tax is a payment to the local authorities for the area of the dwellings and additional land owned by residents. The rate of property tax is 10 shekels/sq. meter for residential space and 0.5 shekels/sq. meter for additional land. For example, a resident who owns a dwelling with an area of 100 sq. meters and additional land of 500 sq. meters pays a total property tax of $100 \cdot 10 + 500 \cdot 0.5 = 1250$.

Residents were divided into three groups:

- A city resident pays property tax for the dwelling area and other land he owns, and receives a grant of 250 shekels for payment of the property tax.
- A senior city resident – a city resident 60+ years old – pays property tax like a city resident, and in addition is eligible for a discount according to his age: 1% discount for each year of life after age 60. The discount is calculated after deducting the grant from the original sum.
- A village resident pays property tax for the dwelling area and other land he owns and is eligible for a discount of 10%. **A village resident 60+ years old is not eligible for the age-dependent discount.**

If the total property tax to be paid, after deducting the discount and the grant, is a negative number, the resident is exempt from payment (pays 0 shekels).

It was decided to develop software for calculation and collection of property taxes from the residents. For this purpose, the following interface was defined:

interface IData

```
{  
    string GetName(); // returns name of resident  
    double GetPropertyTax(); // returns amount of property tax  
}
```

In Items א and ב below, define the classes in accordance with the principles of object-oriented programming and the following requirements:

- Define only once as constants the data for calculating the property tax (payment for dwelling area per sq. meter, payment for land per sq. meter, rate of discount in percent, amount of grant in shekels).
- Define all the attributes that are not constant as `private`.
- א. Define a class Resident (representing a resident), which implements the interface IData, and define in it the attributes of the class (you do not need to write a constructor).

(Note: The question continues on the next page.)

- ב. Define three classes, one for each of the following groups of residents:

CityResident, SeniorCityResident, and VillageResident.

For each of the three groups of residents, define the class attributes and write the method `GetPropertyTax()` that calculates the property tax (you do not need to write a constructor).

- ג. Given: the body of a method that receives an array `a` of residents' data and prints for each senior city resident his name and the amount of property tax he is required to pay:

```
for (int i = 0; i < a.Length; i++)  
{  
    if (a[i] is SeniorCityResident)  
    {  
        Console.WriteLine(a[i].GetName()+" "+a[i].GetPropertyTax());  
    }  
}
```

For each of the following method headers, (1)-(3), indicate whether the method is valid or invalid. If the method is invalid, explain why, correct the method, and copy the corrected method to your answer booklet.

- (1) `public static void Print(Object [] a)`
- (2) `public static void Print(IData [] a)`
- (3) `public static void Print(Resident [] a)`

Good Luck!

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