The State of Israel
Ministry of Education
Exam Type:
א. *Bagrut* for high schools
ב. *Bagrut* for external examinees
Exam Date: Summer 2016
Exam Number: 899205, 603
English Translation (3)

מדינת ישראל
משרד החינוך
סוג הבחינה:
א. בגרות לבתי ספר על־יסודיים
ב. בגרות לנבחנים אקסטרניים
מועד הבחינה: קיץ תשע"ו, 2016
מספר השאלון: 899205, 603
תרגום לאנגלית (3)

Computer Science ב

2 points (*Hashlama* to 5 points)

Instructions for examinees

א. Duration of exam: Three hours
ב. Exam structure and breakdown of points:
This exam has two parts.
Part One –There are four questions in Part One and you must answer two of them.
(2×25) – 50 points
Part Two – In Part Two, there are questions in four different tracks. Answer only the questions for the track in which you studied, according to the instructions for the group of questions for that track.
(2×25) – 50 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 Part One, use only one programming language – Java or C#.
(2) **On the outer cover** of the answer booklet, write which **programming language** you are using – Java or C#.
(3) **On the outer cover** of the answer booklet, write the name of the **track in which you studied**, one of the four tracks:
Computer Systems and Assembly Language,
Introduction to Operations Research,
Computational Models or
Object-Oriented Programming.

Note: In the programs you write, you will not lose points for writing capital 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 ב'

2 יחידות לימוד (השלמה ל-5 יח"ל)

הוראות לנבחן

א. משך הבחינה: שלוש שעות.
ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה שני פרקים.
פרק ראשון – בפרק זה ארבע שאלות ומהן יש לענות על שתיים.
(2×25) — 50 נקודות
פרק שני – בפרק זה שאלות בארבעה מסלולים שונים. ענה על שאלות רק במסלול שלמדת, לפי ההוראות בקבוצת השאלות במסלול זה.
(2×25) — 50 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 בפרק הראשון 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 ה**מסלול 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 two parts: Part One and Part Two.

You must answer questions from both parts, according to the instructions for each part.

Part One (50 points)

Note: For each question that requires implementation, you can use the methods of the classes Queue, Stack, Binary Tree and Link without implementing them.
If you use additional methods, you must implement them.

Answer two of the questions 1-4 (each question – 25 points).

1. This question includes two unrelated items, א-ב.

Answer both of them.

א. A method that accepts a queue q of integers arranged in ascending order [סדר עולה] as a parameter is presented below. All of the numbers are different from one another.

Assume that there are at least two integers in the queue.

Java

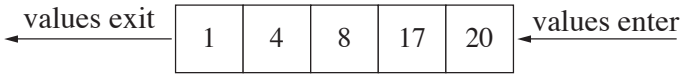
```
public static int what(Queue<Integer > q)
{
        int x = q.remove();
        int y = q.head();
        q.insert(x);
        if (x>y)
              return 0;
        return(what(q) + (y−x));
}
```

C#

```
public static int What(Queue <int > q)
{
        int x = q.Remove();
        int y = q.Head();
        q.Insert(x);
        if (x>y)
              return 0;
        return  (What(q) + (y−x));
}
```

/Continued on page 3/

(1) Given: the queue q1



Trace the method what in Java or the method What in C# for the given queue, q1, and write the value that will be returned. Show the recursive trace.

In your trace, show the values of x and y and the state of the queue after each recursive call [זימון רקורסיבי].

(2) (i) What does the method what in Java or the method What in C# return for a queue q of integers that are arranged in ascending order and are all different from one another?

(ii) How will the queue appear after the method has finished?

(3) If we replace the condition if(x>y) with the condition:

if(q.isEmpty()) in Java

or

if(q.IsEmpty()) in C#

a run-time error will be produced.

What is the error that will be produced? Explain your answer.

(Note: Item ב for this question is on the next page.)

/Continued on page 4/

ב. (No relation to Item א.)

Shown below is a method that accepts a one-dimensional array ar of integers and two integers, x and y, that are each greater than or equal to 0 and smaller than the size of the array; $x \le y$.

Java

```
public static int go(int[] ar , int x , int y)
{
    if ( x == y )   return (ar[x] % 10) ;
    if (( ar[x] % 10) < (ar[y] % 10))
        return go(ar, x + 1, y);
    return   go(ar, x, y−1);
}
```

C#

```
public static int Go(int[] ar , int x , int y)
{
    if ( x == y )   return (ar[x] % 10) ;
    if (( ar[x] % 10) < (ar[y] % 10 ))
        return Go(ar, x + 1, y);
    return   Go(ar, x, y−1);
}
```

An array ar1 of integers is shown below.

	0	1	2	3	4	5	6
ar1	21	219	166	61	127	60	34

(1) What will be returned by the call go(ar1 , 2 , 5) in Java or the call Go(ar1 , 2, 5) in C#?
Show the recursive trace. In the trace, show the values of x , y , ar1[x] and ar1[y] .

(2) What will be returned by the call go(ar1, 0, ar1.length−1) in Java or the call Go(ar1, 0, ar1.Length−1) in C#?

(3) Write what the method does:
in Java: public static int go(int[] ar , int x , int y)
in C#: public static int Go(int[] ar , int x , int y)
for an array ar of integers and two integers, x and y, that are each greater than or equal to 0 and smaller than the size of the array; $x \le y$.

/Continued on page 5/

2. An **integer tree** is a non-empty binary tree of integers, in which the values of the nodes are integers greater than 0 that are all different from one another.

The method "increasing-path" is defined for an **integer tree**. This method will return true if the tree includes a path that begins at its root and ends at one of its leaves and the node values are arranged in ascending order from the root to the leaf.

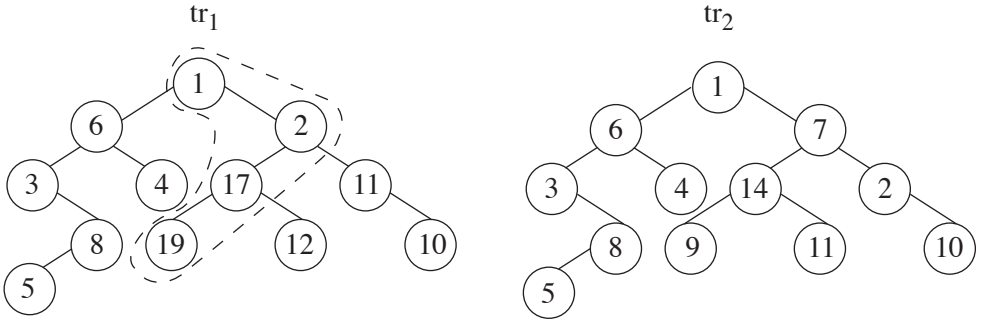
If there is no such path, the method will return false .

For example:

For the **integer tree** tr1, the method "increasing-path" returns true .

The path is indicated by a broken line.

For the **integer tree** tr2, the method "increasing-path" returns false .



Using Java or C#, implement the method "increasing-path" for the **integer tree** tr.

Method declaration in Java: public static boolean upPath(BinNode<Integer> tr)

Method declaration in C#: public static bool UpPath(BinNode<int> tr)

/Continued on page 6/

3. The class **Ring** is shown below. This class has two attributes: the size of the ring, which is a string ("S" — small ring; "L" — large ring), and an integer that represents the color of the ring.

Java

```
public class Ring
{
   private String size;  // ring size
   private int color; // ring color
   public Ring()
   {
      this.size = "L";
      this.color = 0;
   }
   public Ring(String str, int c)
   {
      this.size = str;
      this.color = c;
   }
   public String getSize()
   {
      return this.size;
   }
   public int getColor()
   {
      return this.color;
   }
}
```

C#

```
public class Ring
{
   private string size;  // ring size
   private int color; // ring color
   public Ring()
   {
      this.size = "L";
      this.color = 0;
   }
   public Ring(string str, int c)
   {
      this.size = str;
      this.color = c;
   }
   public string GetSize()
   {
      return this.size;
   }
   public int GetColor()
   {
      return this.color;
   }
}
```

/Continued on page 7/

The interface for the class **Pole** is shown below.

Java	C#	Method
public Pole()	public Pole()	Method that constructs an empty pole. The run-time complexity of the method is O(1).
public void add(Ring r)	public void Add(Ring r)	Method that adds a ring r at the top of the pole. The run-time complexity of the method is O(1).
public Ring remove()	public Ring Remove()	Method that returns the ring that is at the top of the pole. The method also removes the ring from the top of the pole. The run-time complexity of the method is O(1).
public boolean isEmpty()	public bool IsEmpty()	If the pole is empty, the method will return true ; otherwise, it will return false. The run-time complexity of the method is O(1).
public void sort()	public void Sort()	Method that arranges the rings on the pole so that the large rings are at the bottom of the pole underneath the small rings.

א. Implement the method sort() in Java or Sort() in C#, in the class **Pole**. You may use other methods of the class **Pole** without implementing them.

In your answer, use only methods from the classes **Pole** and **Ring**.

ב. What is the run-time complexity of the method you implemented for Item א? Explain your answer.

/Continued on page 8/

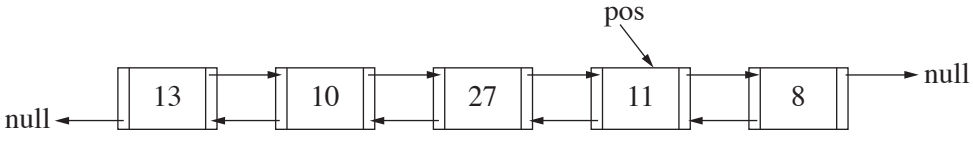
4.

Note: There are two versions of this question —
a version in Java on pages 8-9 and a version in C# on pages 10-11.
Work according to the language that you studied.

For those working in Java

We will define a **bidirectional list** as an ordered collection of links of type BinNode<Integer> that are connected to one another such that:
for each pair of links p2, p1 in the list, if p1.getRight() = = p2 , then p2.getLeft() = = p1 . In a **bidirectional list**, there are at least two links. That is, each link in the list — except for the link on the far right end of the list and the link on the far left end of the list — points to the link that precedes it and the link that comes after it.

A sample **bidirectional list** and a variable pos of type BinNode<Integer> that points to a link in a bidirectional list are shown below.



The method firstLeft accepts a pointer pos that is different from null , of type BinNode<Integer> and points to a link in the bidirectional list.
The method returns the link on the far left end of the list.

The method firstRight accepts a pointer pos that is different from null , of type BinNode<Integer> and points to a link in the bidirectional list.
The method returns the link on the far right end of the list.

א. A skeleton of the method firstLeft is shown below.
Copy it into your answer booklet and fill in the blanks, so that the method will do what is asked.

```
public static BinNode<Integer> firstLeft(BinNode<Integer> pos)
{
    while (_____ )
        pos = _____ ;
    return _____ ;
}
```

/Continued on page 9/

ב. The method what(BinNode<Integer> pos) that receives a pointer for a link in a **bidirectional list** and returns a boolean value is shown below. The **bidirectional list** contains at least 3 links.

(1) Trace the execution of the method for the variable pos and the list presented as an example at the beginning of this question.
In your trace, show the bidirectional list and the values of the variables pos , left , right and sum .

```
public static boolean what(BinNode<Integer> pos)
{
    BinNode<Integer> left = firstLeft(pos);
    BinNode<Integer> right = firstRight(pos);

    int sum = left.getValue() + right.getValue();
    left = left.getRight();
    right = right.getLeft();

    while ((left != right) && (left.getRight() != right) &&
           (left.getValue() + right.getValue() == sum))
    {
        left = left.getRight();
        right = right.getLeft();
    }
    if (left == right)
        return right.getValue() == sum;

    if (left.getRight() == right)
            return left.getValue() + right.getValue() == sum;
    return false;
}
```

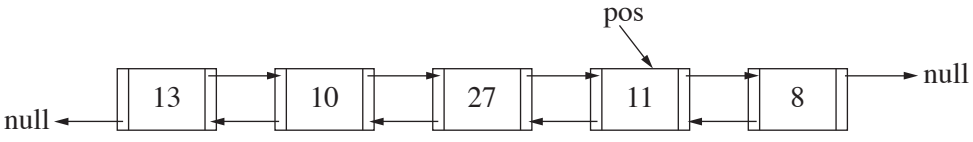
(2) Determine whether or not it is possible to replace the last 3 lines of the method — the lines in the box — with the following command:
return left.getValue() + right.getValue() == sum;
Explain your answer.

/Continued on page 10/

For those working in C#

We will define a **bidirectional list** as an ordered collection of links of type BinNode<Int> that are connected to one another such that:
for each pair of links p1, p2 , if p1.GetRight() = = p2 , then p2.GetLeft() = = p1.
In a **bidirectional list**, there are at least two links. That is, each link in the list — except for the link on the far right end of the list and the link on the far left end of the list — points to the link that precedes it and the link that comes after it.

A sample **bidirectional list** and a variable pos of type BinNode<int> that points to a link in a bidirectional list are shown below.



The method FirstLeft accepts a pointer pos that is different from null , of type BinNode<Int> and points to a link in the bidirectional list.
The method returns the link on the far left end of the list.
The method FirstRight accepts a pointer pos that is different from null , of type BinNode<Int> and points to a link in the bidirectional list.
The method returns the link on the far right end of the list.

א. A skeleton of the method FirstLeft is shown below.
Copy it into your answer booklet and fill in the blanks, so that the method will do what is asked.

```
public static BinNode<int> FirstLeft(BinNode<int> pos)
{
    while (_____ )
        pos = _____ ;
    return _____ ;
}
```

/Continued on page 11/

ב. The method What(BinNode<int> pos) that receives a pointer for a link in a **bidirectional list** and returns a boolean value is shown below.
The **bidirectional list** contains at least 3 links.

(1) Trace the execution of the method for the variable pos and the list presented as an example at the beginning of this question.
In your trace, show the bidirectional list and the values of the variables pos , left , right and sum .

```
public static bool What(BinNode<int> pos)
{
    BinNode<int> left = FirstLeft(pos);
    BinNode<int> right = FirstRight(pos);

    int sum = left.GetValue() + right.GetValue();
    left = left.GetRight();
    right = right.GetLeft();

    while ((left != right) && (left.GetRight() != right) &&
           (left.GetValue() + right.GetValue() == sum))
    {
        left = left.GetRight();
        right = right.GetLeft();
    }
    if (left == right)
        return right.GetValue() == sum;

    if (left.GetRight() == right)
            return left.GetValue() + right.GetValue() == sum;
    return false;
}
```

(2) Determine whether or not it is possible to replace the last 3 lines of the method — the lines in the box — with the following command:
return left.GetValue() + right.GetValue() == sum;
Explain your answer.

/Continued on page 12/

Part Two (50 points)

Part Two includes questions in four different tracks:

Computer Systems and Assembly Language [מערכות מחשב ואסמבלי], pp. 12-18,
Introduction to Operations Research [מבוא לחקר ביצועים], pp. 19-27,
Computational Models [מודלים חישוביים], pp. 28-29,
Object-Oriented Programming [תכנות מונחה עצמים] in Java, pp. 30-39 and
Object-Oriented Programming [תכנות מונחה עצמים] in C#, pp. 40-49.

Answer only the questions for the track in which you studied.

Computer Systems and Assembly Language [מערכות מחשב ואסמבלי]

If you studied in this track, answer two of the questions 5-8 (each question – 25 points).

5. This question includes two unrelated items, א-ב. Answer both of them.

א. In a data section, data are defined as follows:

```
VEC1   DB  45H , 26H , 32H , 82H
VEC2   DB  4 DUP(0)
```

A segment of a program in Assembly language is shown below.

```
START:   MOV   CL , 4
         XOR   CH , CH
         XOR   SI , SI
NEXT:    PUSH  CX
         MOV   AL , VEC1[SI]
         MOV   AH , AL
         AND   AL , 0FH
         MOV   CL , 4
         SHR   AH , CL
         MUL   AH        ;(*)
         MOV   VEC2[SI] , AL
         INC   SI
         POP   CX
         LOOP  NEXT
SOF:     NOP
```

/Continued on page 13/

(1) Using a trace table, trace the execution of the program segment and sketch VEC2 after it has been executed.
Your trace table should include a column for each of the registers [אוגרים] AL, AH, CL, CH and SI.
Draw the stack [מחסנית] at each stage.

(2) What does the program segment do?

(3) In the program segment, in place of the command marked with an asterisk (*), the following command was written: IMUL AH .
Will this change what the program segment does? Explain your answer.

ב. (No relation to Item א.)

A program segment written in Assembly language is shown below.

```
MOV   AX , 14H
MOV   BL , 0AH
DIV   BL
MOV   CL , 4
ROL   AL , CL
OR    AL , AH
```

(1) Using a trace table, trace the execution of the program segment.
Your trace table should include a column for each of the registers AX, AL, AH, BL and CL.

(2) What does the program segment do?

/Continued on page 14/

6. In order to check whether a number can be divided by 6 without any remainder, you can divide it by 2.
If it divides by two without any remainder — divide the result of that division by 3.
If that number divides by 3 without any remainder, the original number can be divided by 6 without any remainder.

א. In Assembly language, write a procedure named DIVBYTWO that will accept a 16-bit number via the stack and store a 0 in AL if that number can be divided by 2 with no remainder. Otherwise, the procedure will store a 1 in AL.
Do not include the command DIV in the procedure.

ב. In Assembly language, write a procedure named DIVBYTHREE that will accept a 16-bit number via the stack and store a 0 in AL if that number can be divided by 3 with no remainder. Otherwise, the procedure will store a 1 in AL.
You may write any commands you wish in the procedure.

ג. In Assembly language, write a procedure named DIVBYSIX that will accept a 16-bit number via the stack and store a 0 in AL if that number can be divided by 6 with no remainder. Otherwise, the procedure will store a 1 in AL.
Use the procedures you wrote for Items א-ב.

ד. In the data segment, an array ARR that has 8 elements, each the length of a word, is defined. The array contains numbers.
In Assembly language, write a program segment that will print the number of elements in the array in which values divisible by 6 with no remainder are stored.
Use the procedure that you wrote for Item ג.

/Continued on page 15/

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

א. Using Assembly language, write a program segment to encrypt a character.

In the data segment, the character is defined as:

```
TAV        DB ?
```

The encryption is done as follows:

The lit bits in the character are counted.

If there is an even number of lit bits, the bits in the character are rotated to the right. The number of times they are rotated is equal to the number of lit bits.

If there is an odd number of lit bits, the bits in the character are rotated to the left. The number of times they are rotated is equal to the number of lit bits.

ב. (No relation to Item א.)

Determine whether each of the statements below (1)-(6) is true or false. If the statement is false, explain why.

(1) A program segment in Assembly language is shown below.

```
MOV   AX , 8
MOV   BX , 2
DIV   BX
```

Upon the completion of the program segment, the register AX will definitely contain 4.

(2) A program segment in Assembly language is shown below.

```
MOV     AL , 56
ADD     AL , 200
JZ      STOP
INC     AL
STOP:
```

Upon the completion of the program segment, the register AX will contain 1.

(Note: This item continues on the next page.) /Continued on page 16/

(3) A program segment in Assembly language is shown below.

```
ARRAY   DW 1, 2, 3, 4
MOV     BX , ARRAY
ADD     BX , 2
MOV     AX , [BX]
```

Upon the completion of the program segment, the register AX will contain 3.

(4) A program segment in Assembly language is shown below.

```
MOV     CX , 3
MOV     AX , 1
DO:
SHL     AX , 1
LOOP    DO
```

Upon the completion of the program segment, the register AX will contain 8.

(5) A program segment in Assembly language is shown below.

```
MOV  AX , 11000001B
MOV  BX , 01000001B
```

The number in AX must be greater than the number in BX.

(6) A command is shown below.

```
OR   AL , 3
```

After this command is executed, the value of AL will always be odd.

/Continued on page 17/

8. This question includes two unrelated items, א-ב. Answer both of them.

א. The number 2 is stored in Register AL and the number 5 is stored in Register BL.

The sum of the numbers from AL through BL (inclusive) should be stored in Register DX.

Three segments in Assembly language, i-iii, are shown below. Using a trace table, trace the execution of each segment and determine whether or not it did what was asked.

i
```
        MOV     DX , 0
        MOV     AH , 0
        MOV     CL , AL
        SUB     CL , BL
AGAIN:  ADD     DX , AX
        INC     AL
        LOOPE   AGAIN
        NOP
```

ii
```
        XOR     DX , DX
        MOV     BH , 0
AGAIN:  ADD     DX , BX
        DEC     BL
        CMP     BL , AL
        JGE     AGAIN
        NOP
```

iii
```
        XOR     DX , DX
        XOR     AX , AX
        MOV     BX , 0
AGAIN:  ADD     DX , AX
        ADD     AX , 1
        CMP     AX , BX
        JL  AGAIN
        NOP
```

(Note: Item ב for this question is on the next page.)

/Continued on page 18/

ב. (No relation to Item א.)

A program segment in Assembly language is shown below.

Note: The numbers are hexadecimal.

```
START:  MOV     AX , 0C72AH
        MOV     BX , 0A98DH
        SHR     AX , 1
        OR      AL , 17H
        NOT     BH
        ADD     AX , BX
```

Using a trace table, trace the execution of the program segment.

The trace table should include a column for each of the flags:

ZF, SF, OF and CF

and each of the registers:

BF and AX.

/Continued on page 19/

Introduction to Operations Research [מבוא לחקר ביצועים]

If you studied in this track, answer two of the questions 9-12 (each question – 25 points).

9. A given linear programming problem:

$\max\{z = (2 + 2k)x_1 + 2x_2\}$

is subject to the following constraints:

(1) $2x_1 + x_2 \leq 10$

(2) $x_1 + x_2 \leq 6$

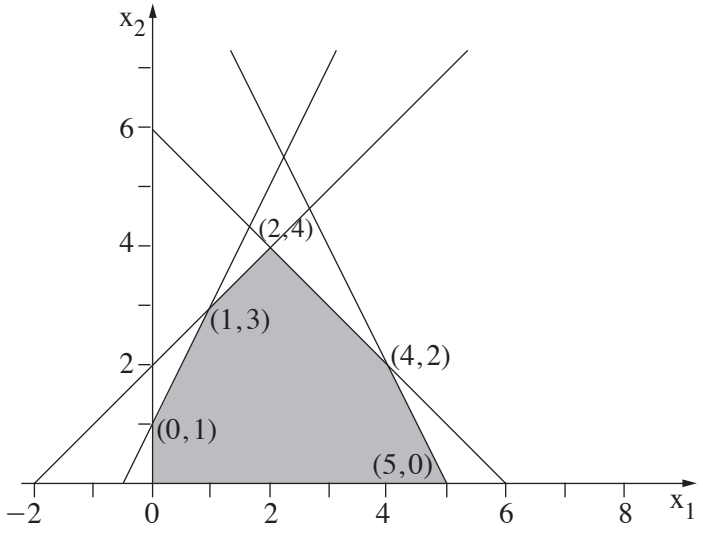
(3) $-x_1 + x_2 \leq 2$

(4) $-2x_1 + x_2 \leq 1$

$x_1 \geq 0$

$x_2 \geq 0$

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



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

/Continued on page 20/

Each of the items א-ד refers to the given linear programming problem. Each item is independent of the others. Answer all of the items.

א. The two sub-items below, (1)-(2), are **independent of one another**.
In each item, a particular value is given for the parameter k.

(1) $k = -1$

(2) $k = -3$

For each of the sub-items (1)-(2), four statements, i-iv, are given below:

i There is a single optimal solution.

ii There are an infinite number of optimal solutions.

iii The optimal solution is not bounded [לא חסום].

iv There is no optimal solution.

Only one of the statements i-iv is correct for each sub-item.
For each of the sub-items (1)-(2), determine which statement is correct, copy that statement into your answer booklet and explain your decision.

— If you determined that Statement i is correct, find the single optimal solution for that sub-item and the value of the objective function for the solution you found.

— If you determined that Statement ii is correct, find the general optimal solution for that problem and the value of the objective function within the range of optimal solutions.

ב. For which values of k will $(2, 4)$ be the optimal solution of the linear programming problem given at the beginning of this question? Explain your answer.

ג. The constraint $x_1 \geq 0$ is removed from the problem given at the beginning of the question, so that $-\infty \leq x_1 \leq \infty$.
Is there a value of k for which the optimal solution will be unbounded? Explain your answer.

ד. In place of the constraint $x_2 \geq 0$ presented for the given problem at the beginning of this question, the constraint $x_2 \geq 4$ was written.
Once this constraint has been changed, does the problem have an optimal solution? If it does, write the solution. If it does not, explain why there is no optimal solution.

/Continued on page 21/

10. This question is made up of two unrelated items, א-ב. Answer both of them.

א. G = (V, E) is a **directed** graph that is represented by this adjacency matrix:

	a	**b**	**c**	**d**	**e**
a	0	1	1	0	0
b	0	0	0	1	0
c	0	1	0	0	0
d	0	0	1	0	1
e	0	1	0	0	0

(1) Sketch the graph G that is represented by the matrix.

(2) Find the strong connected components in the given graph. List the set of vertices for each strong connected component.

(3) For the given graph, find the shortest cycle that contains an even number of edges [קשתות] and sketch that cycle in your answer booklet.

(4) What is the minimum number of edges that can be added to the given graph so that the graph will have only one strong connected component? What edge or edges should be added?

ב. (No relation to Item א.)

G = (V, E) is an **undirected graph** that is represented by the adjacency list shown below:

a	→ b → c → ‖
b	→ a → c → d → e → ‖
c	→ d → a → b → ‖
d	→ c → b → e → ‖
e	→ b → d → ‖

(1) Sketch the graph G that is represented by the adjacency list.

(2) How many connected components are there in Graph G and what are they?

(3) Apply a depth-first search (DFS) algorithm to Graph G starting from Vertex a . In your booklet, sketch only the DFS spanning tree / DFS spanning forest that is obtained. Base your answer on the representation provided by the adjacency list.

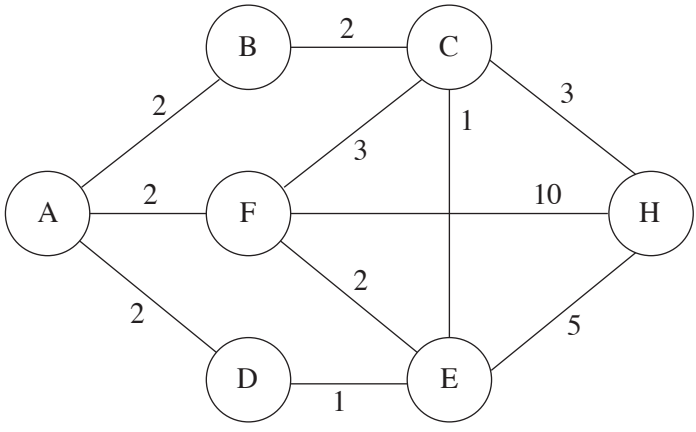
(4) Apply a breadth-first search (BFS) algorithm to Graph G starting from Vertex a . In your booklet, sketch only the BFS spanning tree / BFS spanning forest that is obtained. Base your answer on the representation provided by the adjacency list.

/Continued on page 22/

11. This question is made up of two unrelated items, א-ב. Answer both of them.

א. The network G = (V, E) in which V is the set of vertices in the network and E is the set of edges in the network is shown below.

The weight function $w: E \to R^+$ sets the weight (a number greater than 0) for each edge in the network.



(1) Find all of the shortest paths in the given network from Vertex A to Vertex H.

Present a schematic description of <u>each</u> of the paths that you found.

(2) Find the minimum spanning tree, according to Kruskal's algorithm, from among all of the spanning trees that include the following two edges: (A , B) and (B , C).

Sketch that minimum spanning tree in your answer booklet.

/Continued on page 23/

ב. (No relation to Item א.)

In a given network G = (V, E), V is the set of vertices in the network and E is the set of edges in the network. The weight function $w: E \rightarrow R^+$ sets the weight (a number greater than 0) for each edge in the network.

Also given: the edge e = (a, b) and Vertices s and t in the given network.

The algorithm below returns the value 1 if the given edge e is located on all of the shortest paths from Vertex s to Vertex t. Otherwise, the algorithm returns the value 0.

The algorithm is missing **two** expressions, marked (1) and (2).

Algorithm:

Step 1: Run **Dijkstra**'s algorithm on the network G and assign the length of the shortest path from Vertex s to Vertex t to the variable M1.

Step 2: Build a new network G1 = (V1, E1) in which V1 = V and E1 = __(1)__.

Step 3: Run **Dijkstra**'s algorithm on the network G1 and assign the length of the shortest path from Vertex s to Vertex t to the variable M2.

Step 4: If __(2)__ , return 1.
Otherwise, return 0.

Copy the numbers (1) and (2) into your answer booklet and write the corresponding missing expression next to each number.

/Continued on page 24/

12. This question includes five unrelated items, א-ה. Answer all of them.

א. The table below shows part of a possible basic solution to the transport problem: $x_{11} = 10$.

Origins	**Destinations**				**Supply**
	1	2	3	4	
1	20 (10)	20	30	21	20
2	22	17	29	30	30
3	10	24	26	38	10
Demand	10	20	20	10	

(1) Copy the table into your answer booklet and then complete the possible basic solution according to the north-west corner method.

(2) The price in Cell (3, 1) is changed from 10 to 20. Will this change the possible basic solution you found for Sub-item **(1)**? Explain.

ב. The table below shows a possible basic solution for a transport problem and the value of u_3 for that solution.

Origins	**Destinations**			**Supply**	u_i
	1	2	3		
1	10	8	3 (10)	10	
2	12	15	9 (3)	3	
3	2 (20)	7 (40)	1 (30)	90	0
Demand	20	40	43		
v_j					

(1) Copy the table into your answer booklet and fill in the values for u_1, u_2, v_1, v_2 and v_3.

(2) Explain why the given solution is not an optimal solution.

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

/Continued on page 25/

ג. The table below shows a transport problem and given values of u_1, u_2, u_3, v_1, v_2 and v_3.

Origins	**Destinations**			**Supply**	u_i
	1	2	3		
1	8	8	1	30	1
2	10	12	6	40	6
3	2	7	2	74	1
Demand	30	64	50		
v_j	1	6	0		

(1) Copy the table into your answer booklet and fill in a possible basic solution, taking into account the values of u_1, u_2, u_3, v_1, v_2 and v_3.

(2) In the given table, the cost of transport from Origin 1 to Destination 2 was changed from 8 to 7.
Determine which of the statements i-iv below is correct following this change and copy the correct statement into your answer booklet. Explain your answer.

i The basic solution did not change and it is still the only solution that corresponds to the given values of u_i and v_j.

ii There are **only** two possible basic solutions that correspond to the given values of u_i and v_j.

iii There are an infinite number of possible basic solutions that correspond to the given values of u_i and v_j.

iv Following the change, we cannot find a possible basic solution that corresponds to the given values of u_i and v_j.

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

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٦. The table below shows a given possible basic solution for a transport problem, as well as values of u_1, u_2, u_3, v_1, v_2 and v_3 that correspond to this solution.

Origins	**Destinations**			**Supply**	u_i
	1	2	3		
1	[10]	[8] (10)	[3]	10	1
2	[12]	[15]	[9] (3)	3	8
3	[2] (20)	[7] (30)	[1] (40)	90	0
Demand	20	40	43		
v_j	2	7	1		

Determine which of the statements i-iv below is correct and copy that statement into your answer booklet. Explain your answer.

i The given solution is not a possible basic solution.

ii The given solution is a possible basic solution, but not an optimal solution.

iii The given solution is the only optimal solution.

iv The given solution is an optimal solution, but it is not the only optimal solution.

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

/Continued on page 27/

ה. The table below shows a non-optimal solution that was obtained after k iterations of a certain transport problem, as well as values of u_1, u_2, u_3, v_1, v_2, v_3 and v_4.

Origins	**Destinations**				**Supply**	u_i
	1	2	3	4		
1	[4] (6)	[4] (4)	[14]	[25]	10	3
2	[6]	[1] (5)	[13] (10)	[14] (3)	18	0
3	[0]	[8]	[14]	[12] (2)	2	−2
Demand	6	9	10	5		
v_j	1	1	13	14		

Carry out an additional iteration, that is, iteration k + 1.

(1) In this iteration, what variable exits the base?

(2) In your answer booklet, draw a new table and write the solution that will be obtained after this iteration in that new table.

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Computational Models [מודלים חישוביים]

If you studied in this track, answer two of the questions 13-16
(each question – 25 points).

13. The regular languages L_1 and L_2 are shown below.

$L_1 = \{a^{2n} \mid n \geq 0\}$ over the alphabet {a}

$L_2 = \{b^{2n+1} \mid n \geq 0\}$ over the alphabet {b}

Given: the language L over the alphabet {a, b}

$L = \{a^n b^k \mid n \geq 0\,,\, k \geq 0\,,$ n is even and k is odd or n is odd and k is even$\}$

א. Using only the languages L_1 and L_2 and closure properties, prove that Language L is regular.

ב. Build a non-deterministic finite automaton that will accept Language L.

14. The languages L_1, L_2, L_3 and L_4 are shown below over the alphabet {0, 1}.

$L_1 = \{w \mid$ w includes the sequence 010$\}$

$L_2 = \{w \mid$ w does not include the sequence 00$\}$

$L_3 = \{w \mid$ the number of 0's in w is different from the number of 1's in w$\}$

$L_4 = \{w \mid$ the number of 0's in w is an odd number$\}$

Statements (1)-(6) are presented below.

Determine whether each statement is correct or incorrect.

If the statement is correct, explain why.

If the statement is not correct, explain why or write a word that disproves the statement and explain.

(1) ε belongs to the language $L_1 \cup L_3 \cup L_4$

(2) 00100 belongs to the language $L_1 \cap \overline{L_4}$

(3) $\overline{L_2} = \{w \mid$ w includes the sequence 11$\}$

(4) $L_1 \subseteq L_3$

(5) $L_4 = R(L_4)$

(6) $L_3 \cap L_4 = L_2$

/Continued on page 29/

15. Given: the language L over the alphabet {a, b, c}

$L = \{a^{2n} c^{k} b^{3n+1} \mid n > 0 , k > 0\}$

א. Write the shortest word in Language L.

ב. Construct a pushdown automaton [אוטומט מחסנית] that will accept Language L.

16. Given: a method written in Java and in C#.

The method accepts three integers greater than 0.

Java

```
public static int foo(int x , int y , int z)
{
    if ((x % 3) == 0) return x;
    if ((x % 3) == 1) return y;
    return z;
}
```

C#

```
public static int Foo(int x , int y , int z)
{
    if ((x % 3) == 0) return x;
    if ((x % 3) == 1) return y;
    return z;
}
```

Write a Turing machine that will implement the given method.

The input for the machine is the three numbers x, y and z that the method accepts and this input is written on a tape, starting from the beginning.

Each number is written in a unary manner. The numbers are separated by the symbol #.

For example, if the method receives 2 for x, 3 for y and 1 for z, the tape will look like this:

⊢	1	1	#	1	1	1	#	1	△	△	△	.....

↑

read/write head

The output is the value that the method returns and it will be written as a unary value on the tape at some point between two $ signs.

/Continued on page 30/

Object-Oriented Programming [תכנות מונחה עצמים]

If you studied in this track and you are using Java, answer two of the questions 17-20 (each question – 25 points).

17. This question is made up of two independent items, א-ב. Answer both of them.

א. Five classes are given: B, X, Y, Z and Run. The sub-items (1)-(4) below refer to these classes. The sub-items are independent of one another. Answer all of them.

(1) The following method is defined in each of the classes B, X, Y and Z: `public void foo() {}`
and the following method is defined in class Run:
`public void bar (Object g) {g.foo(); }`
Will there be a compilation error? If so, explain why.

(2) Assume that the classes X, Y and Z inherit the class B.
The following method is defined in each of the classes X, Y and Z:
`public void foo() {}`
and the following method is defined in the class Run:
`public void bar(B g) {g.foo(); }`
Will there be a compilation error? If so, explain why.

(3) Assume that the classes X, Y and Z inherit the class B.
The following method is defined in each of the classes B, X, Y and Z: `public void foo() {}`
and the following method is defined in the class Run:
`public void bar(B g) {g.foo(); }`
Will there be a compilation error? If so, explain why.

(4) Assume that the classes X, Y and Z inherit the class B.
The following method is defined in each of the classes B, X, Y and Z: `public void foo() {}`
and the following method is defined in the class Run:
`public void bar(Object g) {g.foo(); }`
Will there be a compilation error? If so, explain why.

/Continued on page 31/

ב. (No relation to Item א.)
The class **Singer** that inherits the class **Artist**, and the interface **IPerform** that is implemented by the class **Singer** are presented below.

```
interface IPerform
{
   void act();
   int train();
}
public class Singer extends Artist implements IPerform
{
      private int hits;
      public Singer(String name, double sal)
      {
            super(sal, name);
            this.hits = 5;
      }
      public Singer(double sal, int hits)
      {
            super(sal, "Singer Name");
            this.hits = hits;
      }
      public Singer(int hits)
      {
            super(6532.6, "Some", "One");
            this.hits = hits;
      }
      public double value() {return this.hits * this.price();}
      public int getNum()    {return Artist.num;                    }
      public double calc(double d)   {return d * super.calc(10.2);   }
      public void print()      {super.print(); System.out.println("Singer");}
      public void act()        {System.out.println("I am singing");   }
}
```

Using Java, write the declaration of the class **Artist**, the attributes of that class and the method declarations in class **Artist** that are required by the given class **Singer** and the given interface **IPerform**. You do not need to implement the methods of the class **Artist**.
Do not change the class **Singer** or the interface **IPerform**.

/Continued on page 32/

18. The following animals are found in a zoo: lions, platypuses, snakes and turtles.
Lions and platypuses are mammals and snakes and turtles are reptiles.
All of the female reptiles in the zoo lay eggs and the female platypuses also lay eggs.
We want to construct a computerized system that will represent the animals in the zoo. The system will display pictures and animation.
To that end, the following classes have been defined: **Animal**, **Mammal** and **Reptile**. Each animal has an attribute: `name` , and methods: `void move()` and `void turn()` . Animals that lay eggs have the attribute "average number of eggs laid": `numOfEggs` , and a method `int getNumOfEggs()` .

א. Sketch the hierarchy of classes in the zoo and, if necessary, the interfaces, in the manner most appropriate for the principles of object-oriented programming (encapsulation, inheritance and polymorphism).
In your sketch, label the relationships between the classes, as well as the relationships between the classes and the interfaces, if there are any interfaces.
Your sketch does not need to include attributes or methods.

ב. Using Java, for each of the classes in your sketch, write the class declaration, the class attributes and declarations for each of the methods.
You do not need to write the `set` and `get` methods or constructor methods.

ג. The method `String details()` was defined in all of the classes.
This method returns a string made up of the name of the animal, with the names of the classes in the inheritance hierarchy of the animal (beginning with **Animal**) appearing before the name of the animal.
For example, for the object `ln` of type **Lion** whose name is Simba, the method `details` returns the following string: `Animal , Mammal , Lion , Simba .`
For the object `plp` of type **Platypus** whose name is Perry, the method `details` returns the following string: `Animal , Mammal , Platypus , Perry .`

/Continued on page 33/

In Java, implement the method details in the classes **Animal**, **Mammal**, **Lion** and **Platypus**, so that the described strings will be returned. Implement the method in the manner most appropriate for the principles of object-oriented programming (encapsulation, inheritance and polymorphism).

ד. The method toString calls the method details . If the animal lays eggs, the method toString adds the words Number of eggs and the average number of eggs laid to the string, and returns the string.
In Java, implement the method toString in each of the classes in which it appears, in the manner most appropriate for the principles of object-oriented programming (encapsulation, inheritance and polymorphism).

/Continued on page 34/

19. The classes **Bill**, **PhoneBill**, **Shopping** and **MyBills** and the main method in the class Tester are shown below.
Trace the execution of the main method and write the output that will be obtained. Your trace should include the values of the variables and the values of the attributes of each object.

```
public class Bill {
    public final static char DOLLAR = 'd';
    public final static char SHEKEL = 's';
    private static double dollarRate = 4.00;
    private double total;
    private char curr;
    public double getTotal() {
        if (curr == DOLLAR)
            return total * dollarRate;
        return total;
    }
    public Bill(double total, char curr) {
        this.total = total;
        this.curr = curr;
    }
    public String toString() {
        String s = getTotal() + " Shekels";
        return s;
    }
}

public class PhoneBill extends Bill {
    private String company;
    public PhoneBill(String company, double value, char curr) {
        super(value, curr);
        this.company = company;
    }
    public PhoneBill(PhoneBill pb) {
        super(pb.getTotal(), SHEKEL);
        company = pb.company;
    }
    public String toString() {
        String s = "Pay: " + super.toString() + " to: " + company;
        return s;
    }
}
```

/Continued on page 35/

```
public class Shopping extends Bill {
        private String name;
        private String list;
        public Shopping(String name, String list, double value, char curr) {
                super(value, curr);
                this.name = name;
                this.list = list;
        }
        public Shopping(Shopping s) {
                super(s.getTotal(), SHEKEL);
                name = s.name;
                list = s.list;
        }
        public String toString() {
                String s = name + " bought: " + list + ". Pay: " + super.toString();
                return s;
        }
}

public class MyBills {
        private int num;
        private Bill[] bills;
        private final static int MAX = 4;
        public MyBills() {
                bills = new Bill[MAX];
                num = 0;
        }
        public void addBill(Bill b) {
            if (num < MAX) {
                if (b instanceof PhoneBill)
                  bills[num] = new PhoneBill((PhoneBill) b);
                else if (b instanceof Shopping)
                  bills[num] = new Shopping((Shopping) b);
                else num−−;
                num++;
                }
        }
```

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

/Continued on page 36/

```
    public double total() {
        double t = 0;
        for (int i = 0; i < num; i++)
            t = t + bills[i].getTotal();
        return t;
    }
    public void print() {
        for (int i = 0; i < num; i++)
            System.out.println(bills[i].toString());
    }
}

public class Tester {
    public static void main(String[] args) {
        MyBills baba = new MyBills();
        Shopping s = new Shopping("Baba", "Books", 250, Bill.DOLLAR);
        PhoneBill t = new PhoneBill("TeleBaba", 2000, Bill.SHEKEL);
        PhoneBill u = new PhoneBill("Galil Telecom", 200, Bill.DOLLAR);
        baba.addBill(t);
        baba.addBill(s);
        baba.addBill(u);
        baba.print();
        System.out.println(baba.total());
    }
}
```

/Continued on page 37/

20. The classes A and B are shown below.

The three items א-ג refer to these classes, but are independent of one another. Answer all three items.

```
public class A    {
      private int x;
      public A()                { this.x = 0;        }
      public A(int x)           { this.x = x;                }
      public int getX()         { return x;                  }
      public void doubleX()     { this.x = 2 * getX();       }
      public void tripleX()     { this.x = 3 * getX();       }
      public void sub()         { this.x = x-1;              }
      public void calc()        { sub();                     }
      public String toString()     { return "xA="+this.x;  }
}
public class B extends A  {
      private int x;
      public B()                { super();   this.x = 1;              }
      public B(int x)           { super(x);  this.x =-x;              }
      public B(int xA, int xB)  { super(xA); this.x = xB;             }
      public int getX()         { return x;                           }
      public int baseX()        { return super.getX();                }
      public void tenTimesX()   { this.x = 10 * getX();               }
      public void tripleX()     { this.x = 3 * getX();                }
      public void sub()         { this.x = x-2;                       }
      public String toString()  { return super.toString()+" xB="+this.x+";";      }
}
```

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

/Continued on page 38/

א. A series of commands is shown below, for which the output should be:

xA=1 xB=20; xA=1 xB=20; xA=1 xB=20; xA=1 xB=20;

There is a compilation error in the series of commands. Fix the error so that the correct output will be obtained.

```
A a1 = new B(1, 20);
Object obj = a1;
B b1 = a1;
A a2 = a1;
System.out.println(a1+" "+obj+" "+a2+" "+b1);
```

ב. A series of commands is shown below. Present the objects that are produced and the values of the attributes of each object.

```
A aa = new B(3, 10);
aa.sub();
Object[] ar = new Object[6];
ar[0] = new A();
ar[1] = new A(5);
ar[2] = new B();
ar[3] = new B(5);
ar[4] = new B(2, 4);
ar[5] = aa;
((A)ar[3]).tripleX();
((B)ar[4]).tenTimesX();
```

/Continued on page 39/

ג. A main method is shown below.

```
public static void main(String[] args)
{
        A a1 = new A(1);
        A a2 = new B(2, 99);
        //***
}
```

Segments (i)-(iv) are shown below.

(i)
```
a2.doubleX();
System.out.println(a2);
```

(ii)
```
a2.tenTimesX();
System.out.println(a2.tenTimesX());
```

(iii)
```
if (a2 instanceof B)
{
  a2.tenTimesX();
  System.out.println(a2);
}
```

(iv)
```
((B)a1).tenTimesX();
System.out.println(a1);
```

(v)
```
a2.calc();
System.out.println(a2);
```

(vi)
```
B bb = (B)a2;
System.out.println(bb.baseX());
```

For each of the segments (i)-(iv):

- Write the segment in place of //*** in the main method.
- Determine whether or not the segment is valid.
- If the segment is valid, write the output that will be produced once it has been executed.
- If the segment is not valid, is the error a compilation error or a run-time error?

/Continued on page 40/

Object-Oriented Programming [תכנות מונחה עצמים]

If you studied in this track and you are using C#, answer two of the questions 21-24 (each question – 25 points).

21. This question is made up of two independent items, א-ב. Answer both of them.

א. Five classes are given: B, X, Y, Z and Run. The sub-items (1)-(4) below refer to these classes. The sub-items are independent of one another. Answer all of them.

(1) The following method is defined in each of the classes B, X, Y and Z: `public virtual void Foo(){}`
and the following method is defined in class Run:
`public void Bar(Object g) {g.Foo(); }`
Will there be a compilation error? If so, explain why.

(2) Assume that the classes X, Y and Z inherit the class B.
The following method is defined in each of the classes X, Y and Z:
`public virtual void Foo() {}`
and the following method is defined in the class Run:
`public void Bar(B g) {g.Foo(); }`
Will there be a compilation error? If so, explain why.

(3) Assume that the classes X, Y and Z inherit the class B.
The following method is defined in each of the classes B, X, Y, and Z: `public virtual void Foo(){}`
and the following method is defined in the class Run:
`public void Bar(B g) {g.Foo(); }`
Will there be a compilation error? If so, explain why.

(4) Assume that the classes X, Y and Z inherit the class B.
The following method is defined in each of the classes B, X, Y and Z: `public virtual void Foo() {}`
and the following method is defined in the class Run:
`public void Bar(Object g) {g.Foo(); }`
Will there be a compilation error? If so, explain why.

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ב. (No relation to Item א.)

The class **Singer** that inherits the class **Artist**, and the interface **IPerform** that is implemented by the class **Singer** are presented below.

```
interface IPerform
{
    void Act();
    int Train();
}
public class Singer : Artist , IPerform
{
    private int hits;
    public Singer(string name, double sal) : base(sal, name)
    {
        this.hits = 5;
    }
    public Singer(double sal, int hits) : base(sal, "Singer Name")
    {
        this.hits = hits;
    }
    public Singer(int hits) : base(6532.6, "Some", "One")
    {
        this.hits = hits;
    }
    public double Value()          {return this.hits * this.Price(); }
    public int GetNum()            {return Artist.num;               }
    public override double Calc(double d)  {return d * base.Calc(10.2); }
    public override void Print()   {base.Print(); Console.WriteLine("Singer");   }
    public void Act()              {Console.WriteLine("I am singing");          }
}
```

Using C#, write the declaration of the class **Artist**, the attributes of that class and methods in class **Artist** that are required by the given class **Singer** and the given interface **IPerform**. You do not need to implement the methods of the class **Artist**.

Do not change the class **Singer** or the interface **IPerform**.

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22. The following animals are found in a zoo: lions, platypuses, snakes and turtles.

Lions and platypuses are mammals and snakes and turtles are reptiles.

All of the female reptiles in the zoo lay eggs and the female platypuses also lay eggs.

We want to construct a computerized system that will represent the animals in the zoo. The system will show pictures and animation.

To that end, the following classes have been defined: **Animal**, **Mammal** and **Reptile**. Each animal has an attribute: `name` , and methods: `void Move()` and `void Turn()` . Animals that lay eggs have the attribute "average number of eggs laid": `numOfEggs` , and a method `int GetNumOfEggs()` .

א. Sketch the hierarchy of classes in the zoo and, if necessary, the interfaces, in the manner most appropriate for the principles of object-oriented programming (encapsulation, inheritance and polymorphism).

In your sketch, label the relationships between the classes, as well as the relationships between the classes and the interfaces, if there are any interfaces.

Your sketch does not need to include attributes or methods.

ב. Using C#, for each of the classes in your sketch, write the class declaration, the class attributes and declarations for each of the methods. Using C#, write the declaration for each of the interfaces in your sketch, as well as the declaration for each method.

You do not need to write the `Set` and `Get` methods or constructor methods.

ג. The method `string Details()` was defined in all of the classes.

This method returns a string made up of the name of the animal, with the names of the classes in the inheritance hierarchy of the animal (beginning with **Animal**) appearing before the name of the animal.

For example, for the object `ln` of type **Lion** whose name is Simba, the method `Details` returns the following string: `Animal , Mammal , Lion , Simba` .

For the object `plp` of type **Platypus** whose name is Perry, the method `Details` returns the following string: `Animal , Mammal , Platypus , Perry` .

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Using C#, implement the method Details in the classes **Animal**, **Mammal**, **Lion** and **Platypus**, so that the described strings will be returned. Implement the method in the manner most appropriate for the principles of object-oriented programming (encapsulation, inheritance and polymorphism).

7. The method ToString calls the method Details . If the animal lays eggs, the method ToString adds the words Number of eggs and the average number of eggs laid to the string, and returns the string.
Using C#, implement the method ToString in each of the classes in which it appears, in the manner most appropriate for the principles of object-oriented programming (encapsulation, inheritance and polymorphism).

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23. The classes **Bill**, **PhoneBill**, **Shopping** and **MyBills** and the main method in the class Tester are shown below.
Trace the execution of the main method and write the output that will be obtained. Your trace should include the values of the variables and the values of the attributes of each object.

```
public class Bill {
    public const char DOLLAR = 'd';
    public const char SHEKEL = 's';
    private static double dollarRate = 4.00;
    private double total;
    private char curr;
    public double GetTotal()    {
        if (curr == DOLLAR)
            return total * dollarRate;
        return total;
    }
    public Bill(double total, char curr)  {
        this.total = total;
        this.curr = curr;
    }
    public override string ToString()    {
        string s = GetTotal() + " Shekels";
        return s;
    }
}

public class PhoneBill : Bill {
    private string company;
    public PhoneBill(string company, double value, char curr) : base(value, curr) {
        this.company = company;
    }
    public PhoneBill(PhoneBill pb) : base(pb.GetTotal(), SHEKEL){
        company = pb.company;
    }
    public override string ToString() {
        string s = "Pay: " + base.ToString() + " to: " + company;
        return s;
    }
}
```

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```
public class Shopping : Bill {
    private string name;
    private string list;
    public Shopping(string name, string list, double value, char curr) : base(value, curr){
        this.name = name;
        this.list = list;
    }
    public Shopping(Shopping s):base (s.GetTotal(), SHEKEL) {
        name = s.name;
        list = s.list;
    }
    public override string ToString() {
        string s = name + " bought: " + list + ". Pay: " + base.ToString();
        return s;
    }
}
public class MyBills {
    private int num;
    private Bill[] bills;
    private const int MAX = 4;
    public MyBills() {
      bills = new Bill[MAX];
      num = 0;
    }
    public void AddBill(Bill b) {
    if (num < MAX) {
        if (b is PhoneBill)
                bills[num] = new PhoneBill((PhoneBill) b);
        else if (b is Shopping)
            bills[num] = new Shopping((Shopping) b);
        else num−−;
        num++;
        }
    }
```

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

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```
        public double Total() {
            double t = 0;
            for (int i = 0; i < num; i++)
                t = t + bills[i].GetTotal();
            return t;
        }
        public void Print() {
            for (int i = 0; i < num; i++)
                Console.WriteLine(bills[i].ToString());
        }
}


public class Tester  {
        public static void Main(string[] args) {
            MyBills baba = new MyBills();
            Shopping s = new Shopping("Baba", "Books", 250, Bill.DOLLAR);
            PhoneBill t = new PhoneBill("TeleBaba", 2000, Bill.SHEKEL);
            PhoneBill u = new PhoneBill("Galil Telecom", 200, Bill.DOLLAR);
            baba.AddBill(t);
            baba.AddBill(s);
            baba.AddBill(u);
            baba.Print();
            Console.WriteLine(baba.Total());
        }
}
```

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24. The classes A and B are shown below.

The three items א-ג refer to these classes, but are independent of one another. Answer all three items.

```
public class A    {
      private int x;
      public A()                    { this.x = 0;              }
      public A(int x)               { this.x = x;              }
      public virtual int GetX()     { return x;                }
      public void DoubleX()         { this.x = 2 * GetX();     }
      public virtual void TripleX() { this.x = 3 * GetX();     }
      public virtual void Sub()     { this.x = x-1;            }
      public void Calc()            { Sub();                   }
      public override string ToString(){ return "xA="+this.x;  }
}
public class B:A  {
      private int x;
      public B() : base()           { this.x = 1;              }
      public B(int x) : base(x)     { this.x =-x;              }
      public B(int xA, int xB) : base(xA)     { this.x = xB;   }
      public override int GetX()    { return x;                }
      public int BaseX()            { return base.GetX();      }
      public void TenTimesX()       { this.x = 10 * GetX();    }
      public override void TripleX() { this.x = 3 * GetX();    }
      public override void Sub()    { this.x = x-2;            }
      public override string ToString(){ return base.ToString()+" xB="+this.x+";";}
}
```

(Note: This question continues on the next two pages.)

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א. A series of commands is shown below, for which the output should be:
xA=1 xB=20; xA=1 xB=20; xA=1 xB=20; xA=1 xB=20;
There is a compilation error in the series of commands. Fix the error so that the correct output will be obtained.

```
A a1 = new B(1, 20);
Object obj = a1;
B b1 = a1;
A a2 = a1;
Console.WriteLine(a1+" "+obj+" "+a2+" "+b1);
```

ב. A series of commands is shown below. Present the objects that are produced and the values of the attributes of each object.

```
A aa = new B(3, 10);
aa.Sub();
Object[] ar = new Object[6];
ar[0] = new A();
ar[1] = new A(5);
ar[2] = new B();
ar[3] = new B(5);
ar[4] = new B(2, 4);
ar[5] = aa;
((A)ar[3]).TripleX();
((B)ar[4]).TenTimesX();
```

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ג. A main method is shown below.

```
public static void Main()
{
        A a1 = new A(1);
        A a2 = new B(2, 99);
        //***
}
```

The segments (i)-(vi) are shown below.

```
(i)   a2.DoubleX();
      Console.WriteLine(a2);
(ii)  a2.TenTimesX();
      Console.WriteLine(a2.TenTimesX());
(iii) if (a2 is B)
      {
        a2.TenTimesX();
        Console.WriteLine(a2);
      }
(iv)  ((B)a1).TenTimesX();
      Console.WriteLine(a1);
(v)   a2.Calc();
      Console.WriteLine(a2);
(vi)  B bb = (B)a2;
      Console.WriteLine(bb.BaseX());
```

For each of the segments (i)-(vi):

- Write the segment in place of //*** in the main method.
- Determine whether or not the segment is valid.
- If the segment is valid, write the output that will be produced once it has been executed.
- If the segment is not valid, is the error a compilation error or a run-time error?

Good Luck!

בהצלחה!