MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION
Federal State Autonomous Educational Institution of Higher Education " NORTH CAUCASUS FEDERAL UNIVERSITY "

EDUCATIONAL AND METHODOLOGICAL GUIDE FOR PRACTICAL CLASSES IN THE DISCIPLINE

Mathematical Modeling

Training direction 11.03.02 Infocommunication technologies and communication systems

Profile: Intelligent Data Processing in Infocommunication Systems and Networks

Stavropol 2026

Introduction

The practical training includes five assignments, as outlined in the course's curriculum. Each assignment includes the title, objective, assignments with a set of initial data options, examples of programming, report content requirements, and quizzes.

In preparation for the practical lesson, students must study the theoretical material from the lecture notes included in the EMCD, as well as the referenced literature, and carefully work through examples and problems on the relevant topic. After completing each task and submitting a report, the student must defend it. During this process, the student must provide well-reasoned answers to all questions related to the work and the analysis of the results.

Practical classes are carried out in a computer lab on a personal computer using the GPSS simulation package. World and the Excel package . The GPSS simulation system is best suited for modeling real-world objects, which can be represented as one or more queueing system (QS) nodes. The GPSS modeling language includes specialized tools for modeling request flows, single-channel and multi-channel QS nodes, queues, etc. The GPSS language allows for modeling virtually any QS: open and closed, single-channel and multi-channel, with unlimited queues, failures, queue constraints, etc. The main QS characteristics (node load factors, queue lengths, etc.) are automatically determined during the modeling process and output as part of the model's output. At the same time, the GPSS language can be used to solve system modeling problems that are not typically described using a QS. The GPSS system is based on the Monte Carlo method, and Monte Carlo operations (calls to random number generators, condition checking, etc.) are performed automatically in the GPSS language, i.e., they are hidden from the user. However, if necessary, the user can implement the operations of this method in a GPSS program. These lab exercises utilize one of the implementations of the modern GPSS modeling system—the GPSS World system.

The second part of the practical exercises focuses on the efficient use of IS servers, ensuring their optimal load, and developing and implementing optimal algorithms for distributing load across data center cluster servers. Five servers of various configurations were used to solve this problem. The servers were taken from one of Amazon 's services .

Elastic Compute Cloud (Amazon EC 2). During the development of this project, an algorithm for allocating data center server resources is selected. This requires creating a data center resource matrix, then entering all the technical specifications of the servers used (number of virtual processors, processor performance, random access memory (RAM) capacity, hard drive capacity, and network bandwidth) into an Excel spreadsheet. Next, create a mathematical model for optimal resource allocation and solve the problem using Excel .

Contents of the report

report is submitted for defense in printed form. During the defense, the student must provide reasoned answers to all questions related to the work and analysis of the results. The report must contain the following information:

- task according to the option;
- program algorithm;
- program listing;
- output statistics and its analysis, conclusions.

Practical lesson #1

Topic: Development of a simulation model managing network packet queues on IEEE 802.11 wireless routers

Questions

1. Analysis of queue management algorithms network packets on IEEE 802.11 wireless routers.

2. Development and research of models managing network packet queues on wireless routers.

3. Experimental research, obtaining quantitative results and their analysis, conclusions.

Objective: To improve the efficiency of information interaction during network data exchange in wireless systems.

A simulation model (program) in GPSS World is a sequence of statements (called blocks) representing events occurring in the QS as transactions move . Since GPSS interpreters implement an event-driven method and the QS can have multiple transactions running simultaneously, the interpreter will alternately execute different program fragments, simulating the progress of transactions at the current moment in time until they are delayed in certain devices or queues.

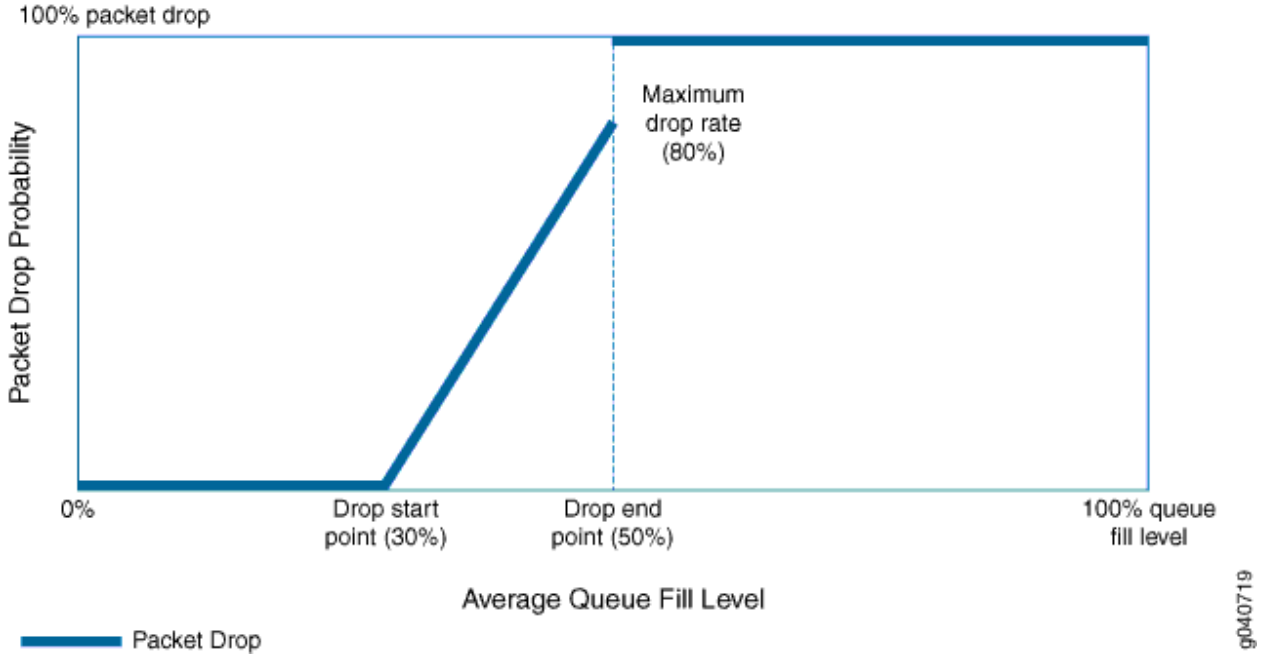
This lab examines the operation of three network router queue management algorithms:

1. Drop Tail
2. RED
3. RiO .

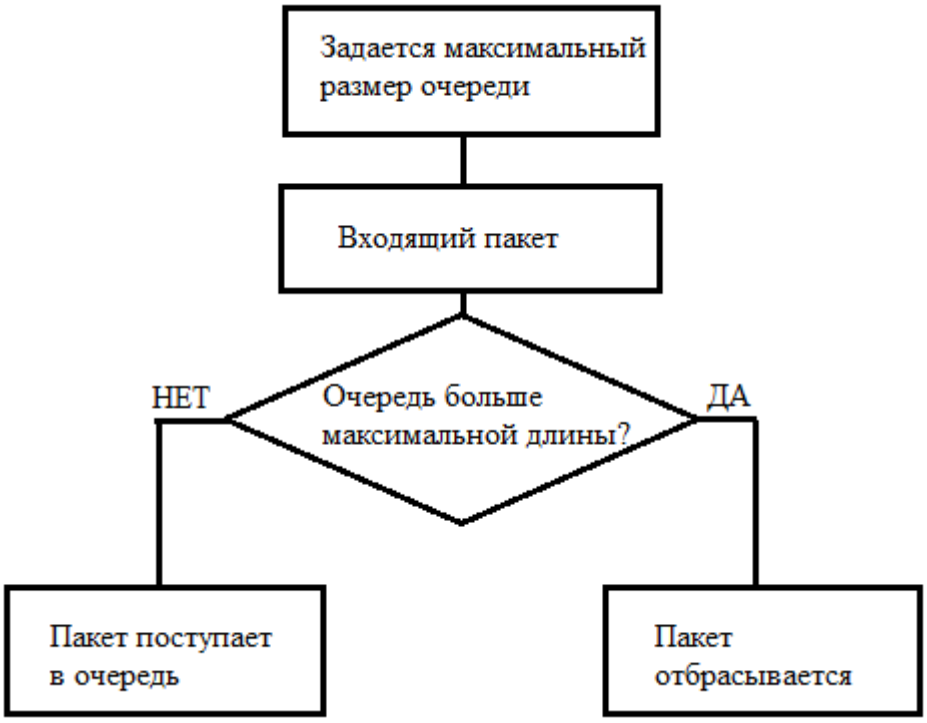
Tail Drop is one of the simplest algorithms for managing router queue congestion . Unlike more complex algorithms such as RED and WRED , Tail Drop does not separate traffic by packet type.

The principle of the algorithm: the maximum size of the queue is set (in packets or bytes), a newly arriving packet is placed at the end of the queue, when the queue is filled to some specified maximum size, all newly arriving packets are discarded until the queue has enough space to accommodate incoming traffic.

Drop Tail algorithm works



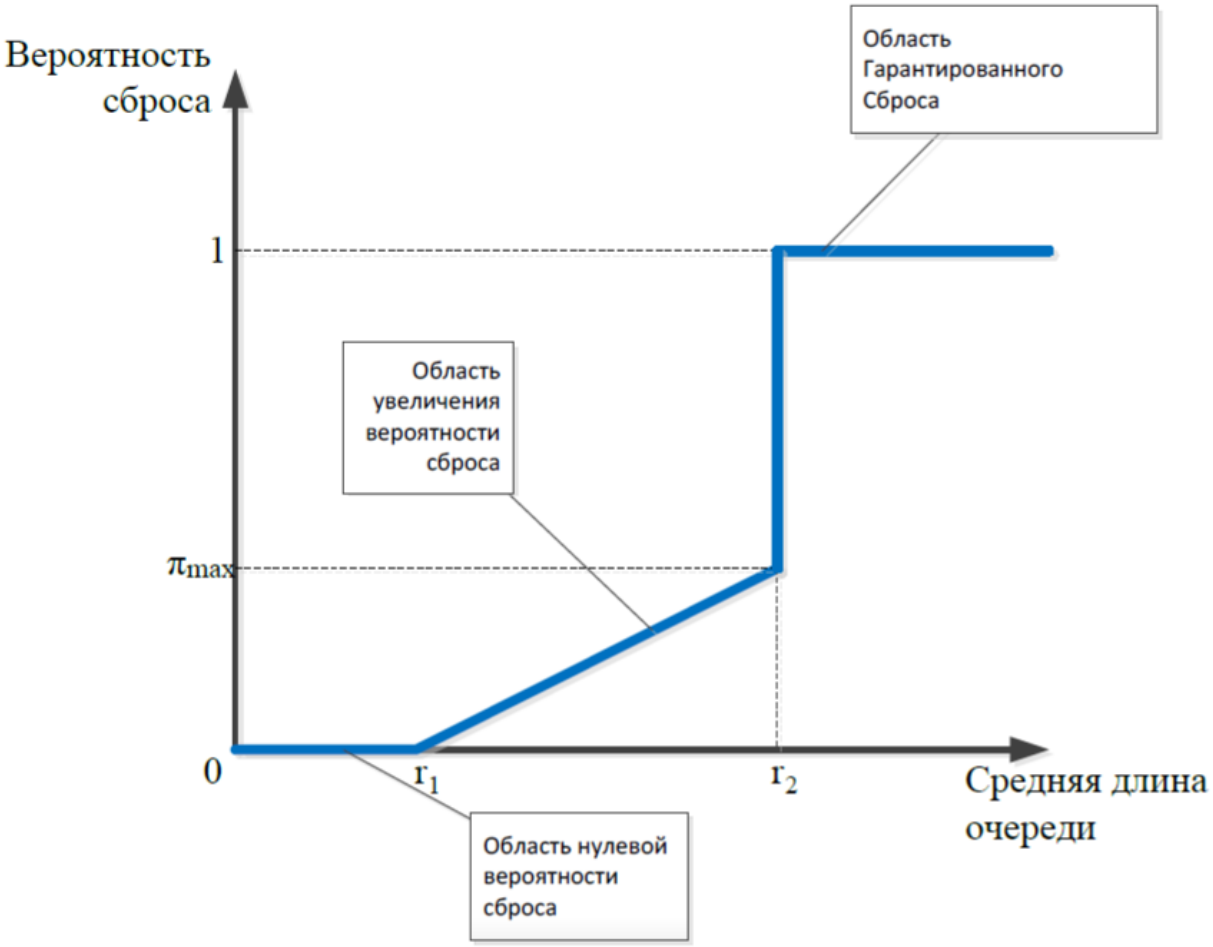
Block diagram of the DropTail algorithm



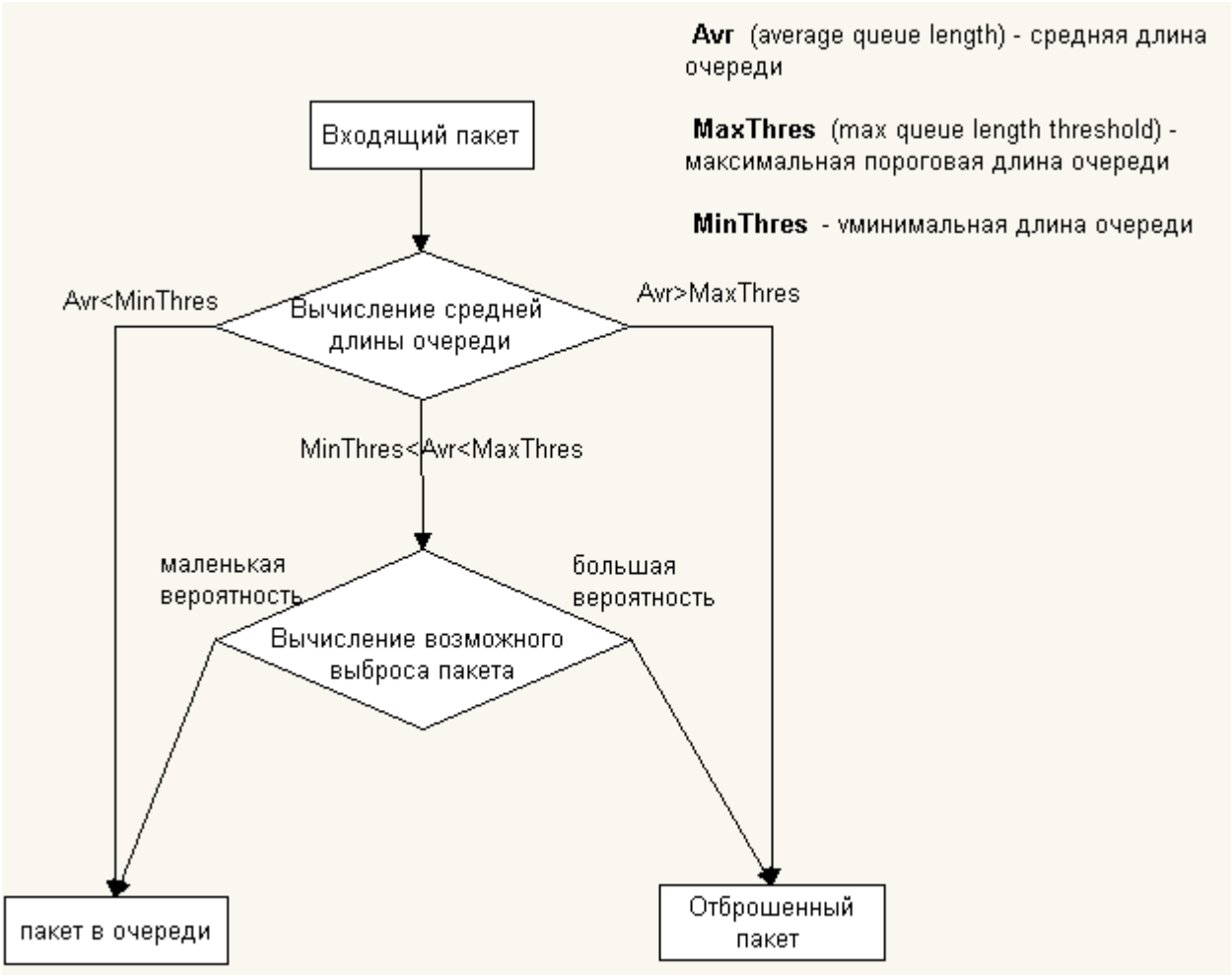
Random early detection (RED) is one of the AQM algorithms for managing router queue congestion.

Algorithm Principle: RED tracks the average queue size and dropped packets based on statistical probability. RED can also use ECN tracking . When a router's buffer occupancy exceeds a threshold, the probability of dropping an incoming packet depends on the degree to which the threshold is exceeded.

The operating principle of the RED algorithm



RED algorithm flowchart



Description of the RED algorithm

The algorithm consists of two parts: estimating the average queue size and deciding whether to discard a newly arrived packet.

each new packet using a high-pass filter in conjunction with an exponentially weighted moving average (EWMA) (low-pass filter)

with an exponentially weighed moving average), RED determines average

The queue size avg. The avg value is then compared with the previously defined upper and lower boundaries, max_th and min_th, which determine the load on the queue.

If the avg value belongs to the interval [0; min th], then the incoming packet is placed in the queue. If the avg value belongs to the interval [min_th; max_th], then the probability of packet drop Pa is calculated, and either the incoming packet is dropped with probability P0, or with probability (1 - P0) the incoming packet is placed in the queue. If the average queue size avg exceeds the max_th value, then the incoming packet is necessarily dropped. Note that the probability of packet drop is a function of the avg variable, i.e., as the load increases, the probability of incoming packet drop increases. It should be noted that RED also has the ability to perform marking rather than packet drop.

Marking can be performed by changing a bit in an optional field in the packet header in order to notify the transport layer protocol, for example, TCP, of impending congestion. In this case, if the receiver implements a protocol that understands packet marking, the receiver protocol should lower the window size, thereby signaling the source to reduce the load. As a result, the source should lower the window size, thereby reducing the number of packets transmitted into the network over a certain period of time. The implementation of packet marking in RED is more efficient than the implementation of discarding when a protocol like TCP operates at the transport layer, and when UDP flow control is implemented, RED must implement the discard function. Thus, RED consists of two different algorithms: the algorithm for calculating the average queue size effectively calculates the degree of burstiness of the load that can be accommodated by the buffer; the algorithm for calculating the probability of marking or discarding a packet based on the known load value (i.e., the average queue length) determines how often the router marks or discards packets.

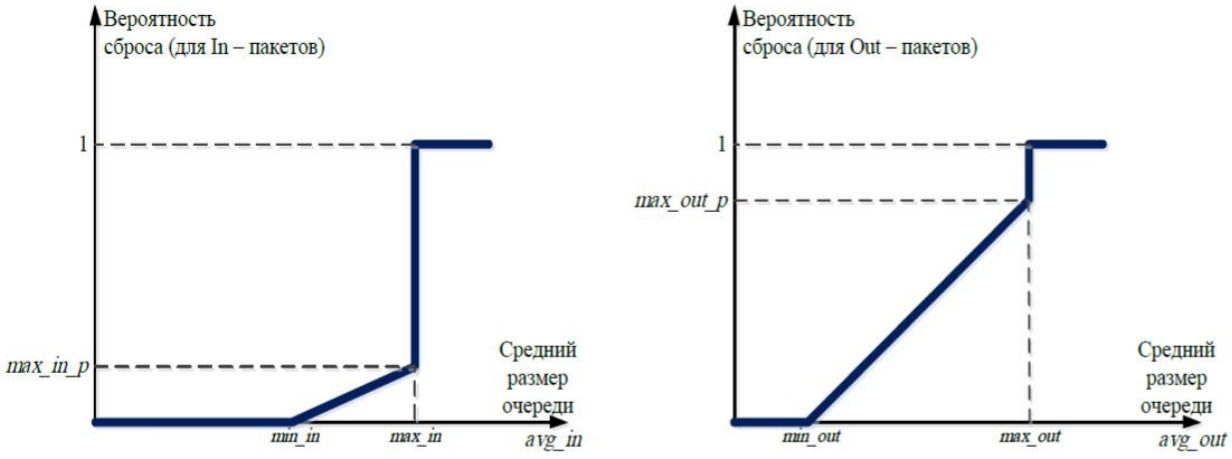
The purpose of RED operation in a router is to implement packet marking/dropping in such a way that the principle of "fair distribution of resources" is observed and "global synchronization" is avoided.

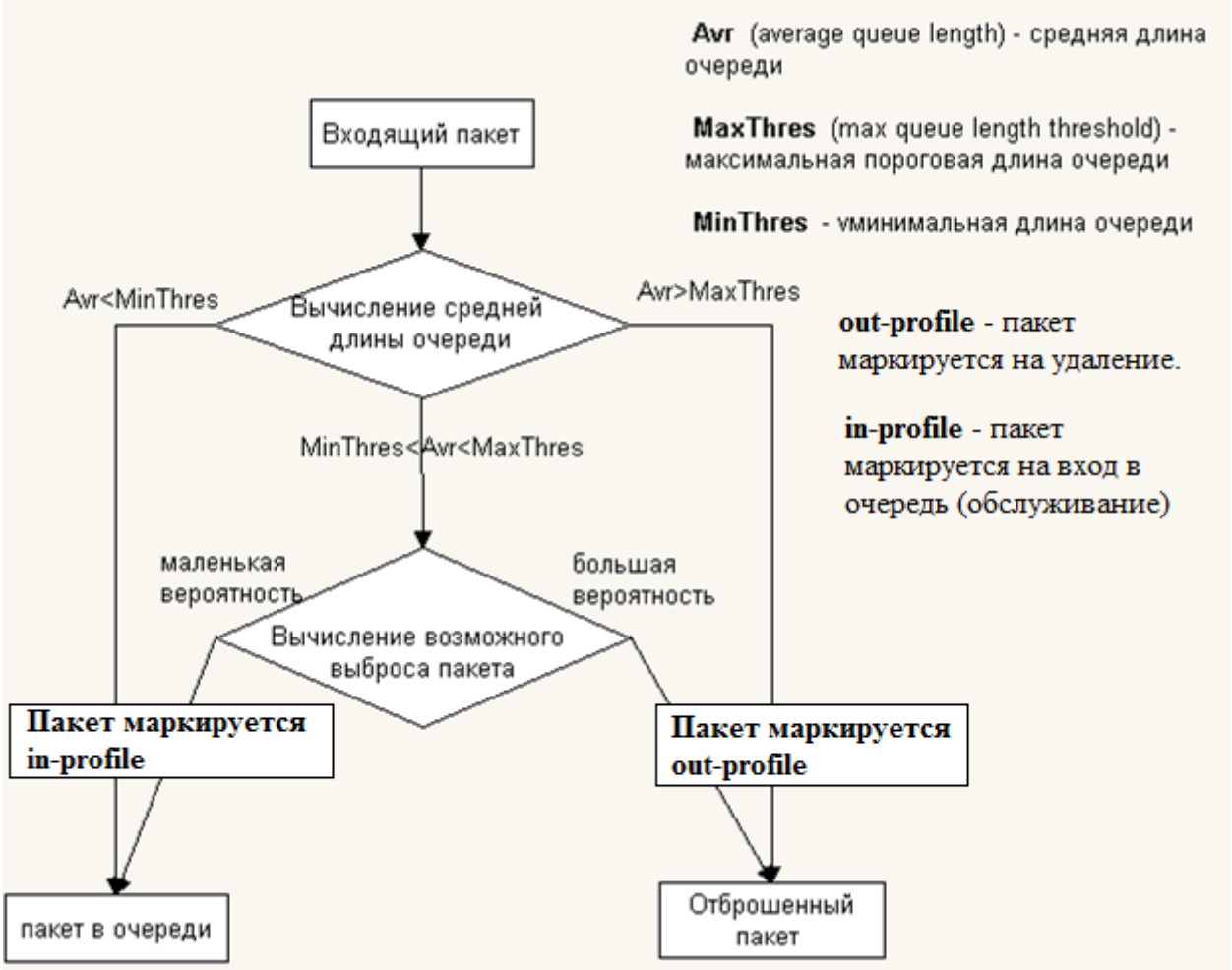
RIO algorithm

RIO (RED In & Out) queue management algorithm is completely analogous to the RED algorithm, except that it is parameterized by two sets of parameter values—each set for a separate class of packets. It is assumed that there are two classes of packets: *unmarked (in-profile),* i.e., when a packet belongs to a flow whose parameter values do not exceed predefined values, and *marked (out-profile),* i.e., when a packet belongs to a flow whose parameter values exceed predefined values. RIO distinguishes between these two classes of packets by analyzing the packet header and is therefore able to discard marked packets with a higher probability than untagged ones, thus providing protection against discarding untagged packets.

Since the RIO algorithm is a modification of the RED algorithm, it's clear that the operating principles of these algorithms are identical. In fact, RIO is a more complex version of RED, as it requires monitoring two sets of parameters: one for low-priority (untagged) packets and one for high-priority (marked) packets.

The operating principle of the RIO algorithm





Let's consider the operating principle of the RIO algorithm . Obviously, when a packet enters the queue, it is necessary to determine which class this packet belongs to. If the packet is unmarked (for simplicity, we will further call such a packet an In packet), then the average is calculated.

its queue size avg _ in , which consists only of In -packets. If

marked packet (for simplicity, we will further call such a packet an Out packet), then the average size of the entire queue is calculated

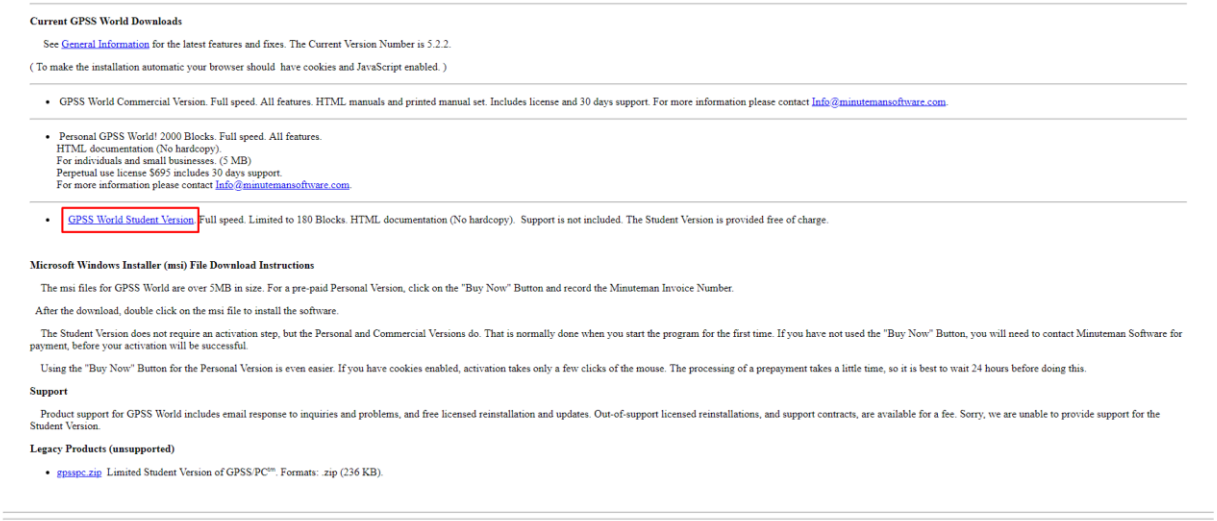
avg _ total . It is worth noting here an important detail that the probability of dropping an In packet depends on the average size of the queue consisting only of In packets, while the probability of dropping an Out packet depends on the average size of the queue consisting of packets of both classes, In packets and Out packets. Note that all packets, regardless of their class, arrive at the same

FIFO queue . A queue consisting only of In packets does not physically exist; its size is calculated by a special

procedure. The figure shows the packet drop probability functions depending on the average queue size for In -packets and Out -packets. As can be seen and expected from the operating principles of the RED algorithm , the following operating parameters must be determined for each packet class:

- Min_in : lower bound for In packets ;
- Max_in : upper bound for In packets ;
- Min_out : lower bound for Out packets ;
- Max_out : upper bound for Out packets ;
- Max _ in _ p : maximum value of the drop probability for In -packets;
- Max_out_p : maximum value of the discard probability for Out packets .

To complete this lab you will need the GPSS program interpreter. World . The software can be downloaded from http://www.minutemansoftware.com/downloads.asp . To install GPSS , follow the link and click the **"GPSS World Student Version" button:**



Current GPSS World Downloads

See General Information for the latest features and fixes. The Current Version Number is 5.2.2.

(To make the installation automatic your browser should have cookies and JavaScript enabled.)

- GPSS World Commercial Version. Full speed. All features. HTML manuals and printed manual set. Includes license and 30 days support. For more information please contact Info@minutemansoftware.com.

- Personal GPSS World! 2000 Blocks. Full speed. All features.
  HTML documentation (No hardcopy).
  For individuals and small businesses. (5 MB)
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  For more information please contact Info@minutemansoftware.com.

- GPSS World Student Version. Full speed. Limited to 180 Blocks. HTML documentation (No hardcopy). Support is not included. The Student Version is provided free of charge.

Microsoft Windows Installer (msi) File Download Instructions

The msi files for GPSS World are over 5MB in size. For a pre-paid Personal Version, click on the "Buy Now" Button and record the Minuteman Invoice Number.

After the download, double click on the msi file to install the software.

The Student Version does not require an activation step, but the Personal and Commercial Versions do. That is normally done when you start the program for the first time. If you have not used the "Buy Now" Button, you will need to contact Minuteman Software for payment, before your activation will be successful.

Using the "Buy Now" Button for the Personal Version is even easier. If you have cookies enabled, activation takes only a few clicks of the mouse. The processing of a prepayment takes a little time, so it is best to wait 24 hours before doing this.

Support

Product support for GPSS World includes email response to inquiries and problems, and free licensed reinstallation and updates. Out-of-support licensed reinstallations, and support contracts, are available for a fee. Sorry, we are unable to provide support for the Student Version.

Legacy Products (unsupported)

- gpsspc.zip Limited Student Version of GPSS/PC™. Formats: .zip (236 KB).

Minuteman Software
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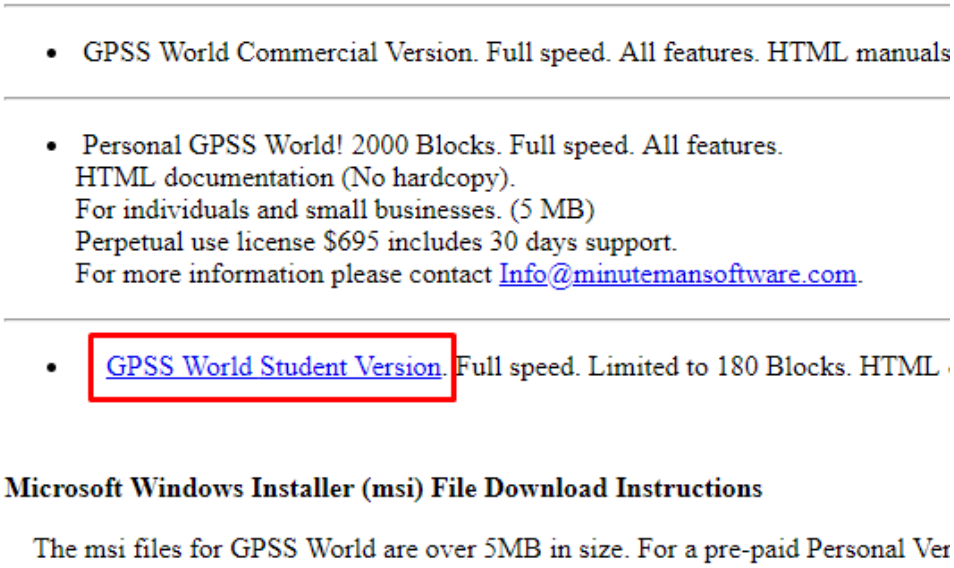
Drawing 1Full page download



- GPSS World Commercial Version. Full speed. All features. HTML manuals

- Personal GPSS World! 2000 Blocks. Full speed. All features.
  HTML documentation (No hardcopy).
  For individuals and small businesses. (5 MB)
  Perpetual use license $695 includes 30 days support.
  For more information please contact Info@minutemansoftware.com.

- GPSS World Student Version. Full speed. Limited to 180 Blocks. HTML

Microsoft Windows Installer (msi) File Download Instructions

The msi files for GPSS World are over 5MB in size. For a pre-paid Personal Ver

Drawing 2to scale

The installer will then download from the website. Installation is simple: click " **Next " at each step .** Launch the program and go to **the File - New tab .** Next, select **Model and** click **Ok .** Let's check the system's operation by running a simple program.

GENERATE 1 ; Time to generate one transaction

TERMINATE 1 ; Delete one transaction

START 10 ; Simulation time 10 time units

To launch the program, go to **the Command - Create tab. Simulation .**

As a result, two windows should appear: an error log and a report listing.

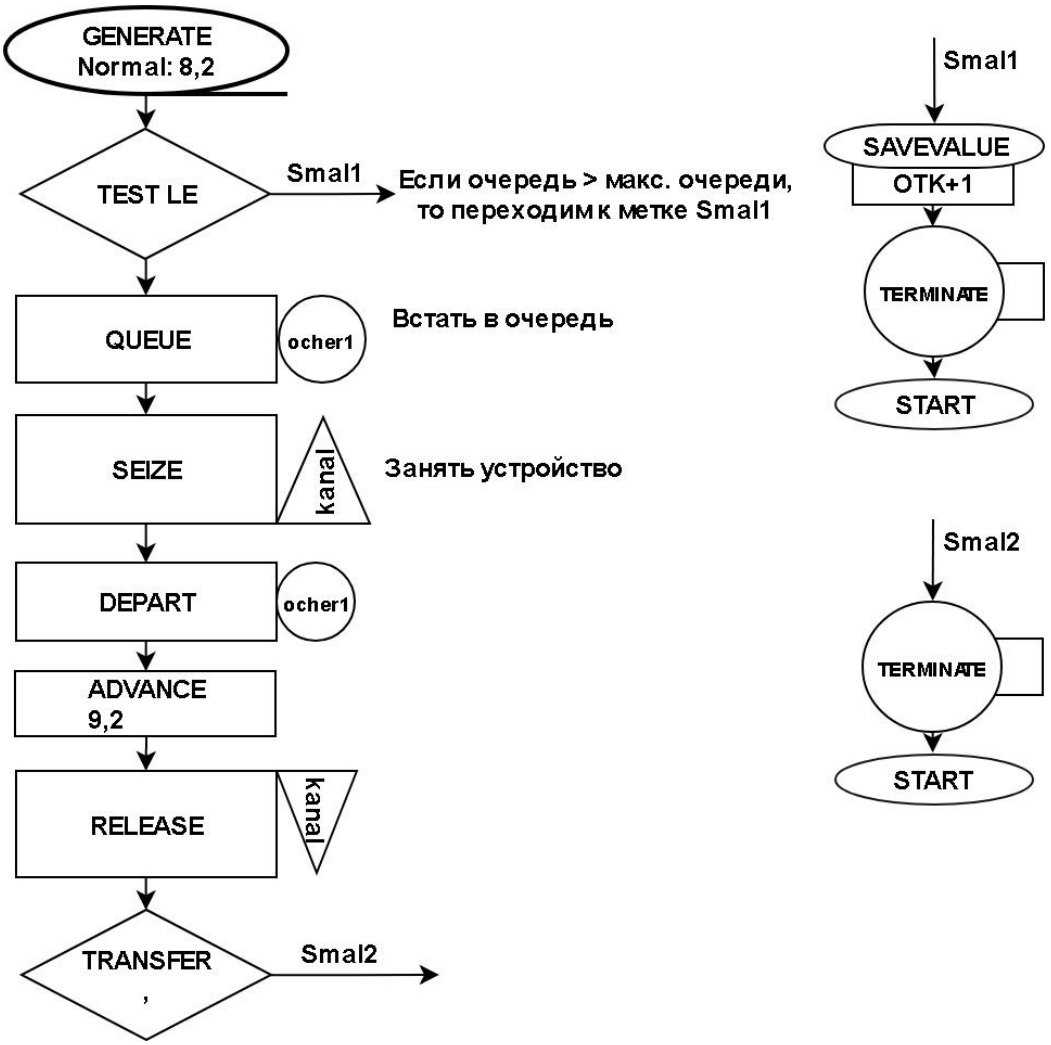
Task 1. Drop Algorithm Tail

GPSS application . To start working with algorithms, select *Open in the control panel* and select the document with the **Drop algorithm. Tail** . The program will open a document with the selected algorithm:

Code listing of the Drop algorithm model Tail

```
Wait          QTABLEocher1,0,2,50
MaxOcher      EQU10
    GENERATE 8.2
    TEST LQ$ocher1,MaxOcher,smal1
    QUEUEocher1
    SEIZEkanal
    DEPARTocher1
    ADVANCE 9.2
    RELEASEkanal
    TRANSFER, small2
smal1         SAVEVALUEotk+,1
smal2         TERMINATE 0
    GENERATE1000
    TERMINATE 1
    START 1
```

Algorithm flow chart



Description code programs

1. Wait Block QTABLE creates a table ocher 1 of the waiting time in the packet queue.
2. EQU sets the MaxOcher variable to 10.
3. Generate generates transactions.
4. TEST Block L compares two values. If the queue ocher 1 is less than the maximum queue MaxOcher , the transaction proceeds. Otherwise, it moves to the label small 1, where the SAVEVALUE block increments the value of dropped packets by 1. The packet then moves to the TERMINATE block , which destroys it.
5. The QUEUE block places the packet in queue ocher 1 for subsequent transmission over the communication channel.
6. SEIZE block simulates the preparation of a packet for transmission.
7. DEPART block sends a packet to the communication channel.
8. ADVANCE block simulates the processing (transmission) of a packet.
9. RELEASE releases the channel.

Select Command -> Create from the control panel. Simulation . The program creates a report. This report reflects all the information about the test performed. The program's output will look something like this:

Results of the model execution

SAVEVALUE	RETRY	VALUE
OTK	0	85.000

FACILITY	ENTRIES	UTIL.	AVE. TIME	AVAIL.	OWNER	PEND	INTER	RETRY	DELAY
KANAL	141	0.994	7.047	1	190	0	0	0	9

QUEUE	MAX	CONT.	ENTRY	ENTRY(0)	AVE.CONT.	AVE.TIME	AVE.(-0)	RETRY
OCHER1	10	9	150	1	9.050	60.332	60.737	0

TABLE	MEAN	STD.DEV.	RANGE	RETRY	FREQUENCY	CUM.%
WAIT	62.031	15.115		0		

Drawing3 Drop Tail - REPORT , the simulation report window

From this report we obtained the following results *:*

1. *Number of dropped packets: 85;*
2. *Number of packets passed: 141;*
3. *Channel load factor: 0.994;*
4. *Average package service time: 7.047;*
5. *Maximum queue length: 10;*
6. *Average queue length: 9,050;*
7. *Average queue time: 60.332.*

After the report has been created, select Window -> Simulation Window -> Plot Window . In the window that appears, you must fill in the following:

Label – just the name of the table, doesn't affect anything

Expression – we point to the table with the queue, in this case** **(in these 3 algorithms)** write – " Q $ queue 1"

Title – not necessarily

Time Range – simulation interval, (in this case**) write 1000

Max Value – the maximum value of the queue, (in this case**) write 10

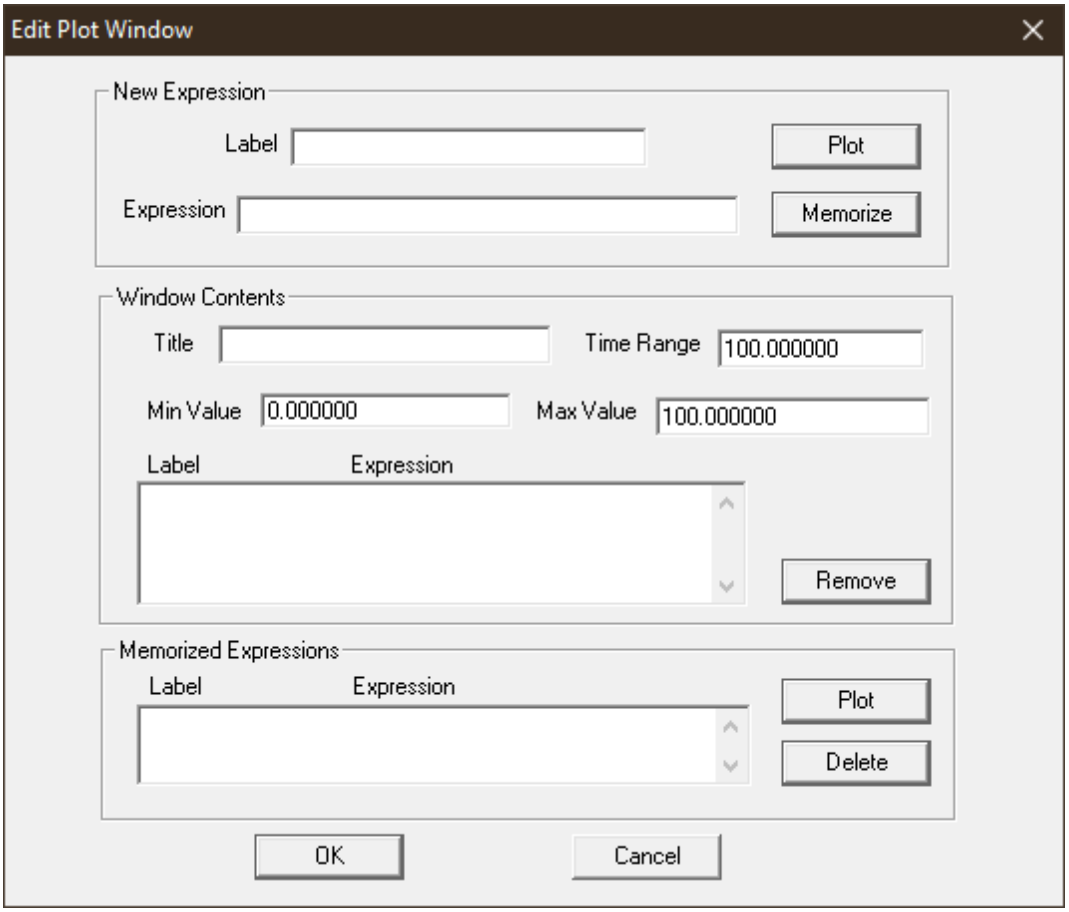


Figure: 4Graph creation window

After filling in all the parameters, click on the “ Memorize ” button.

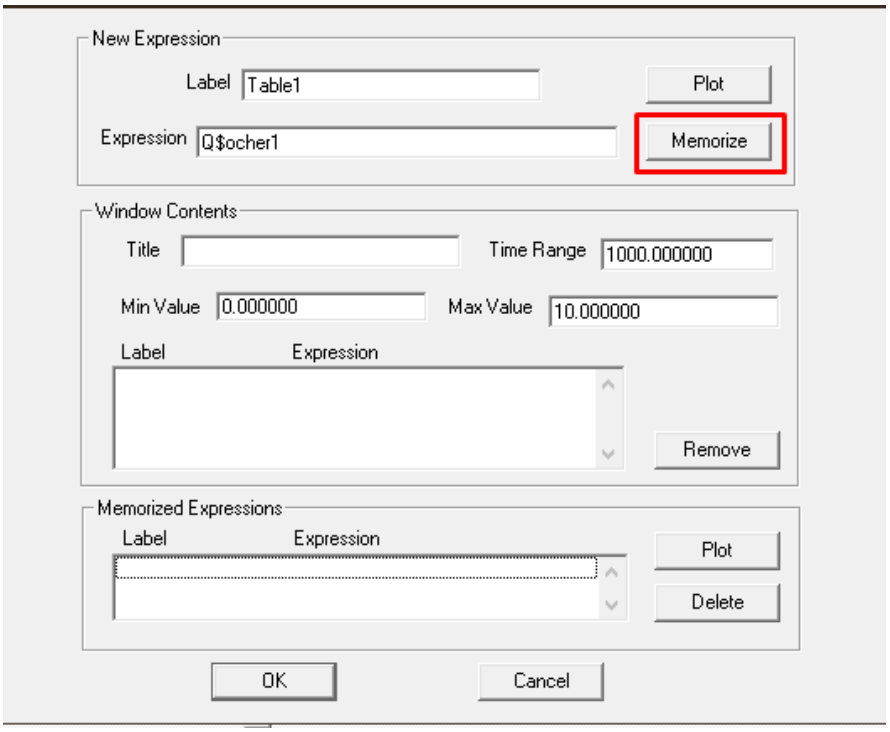
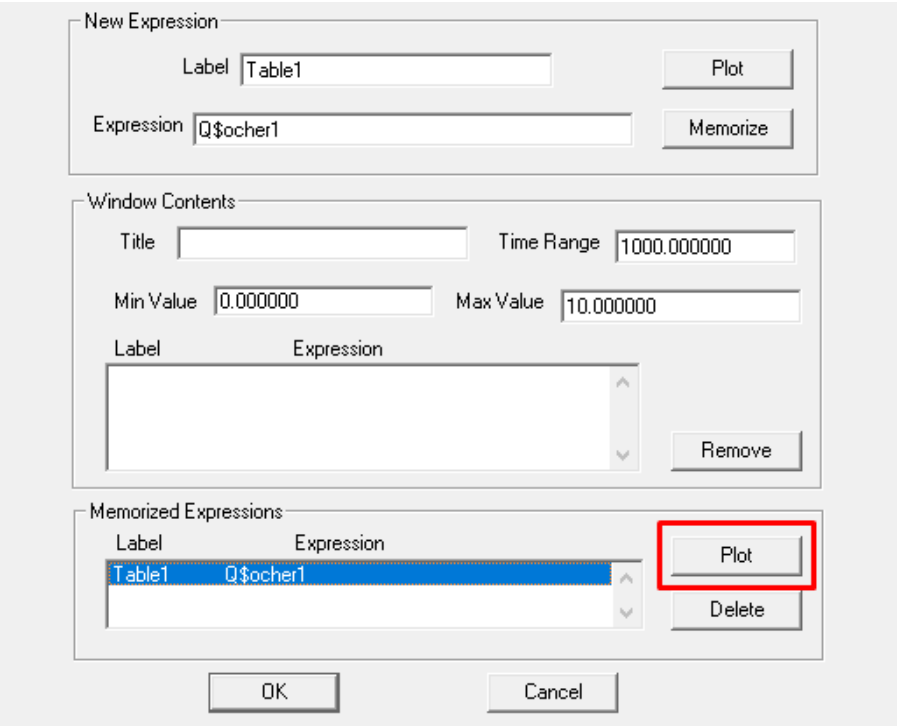
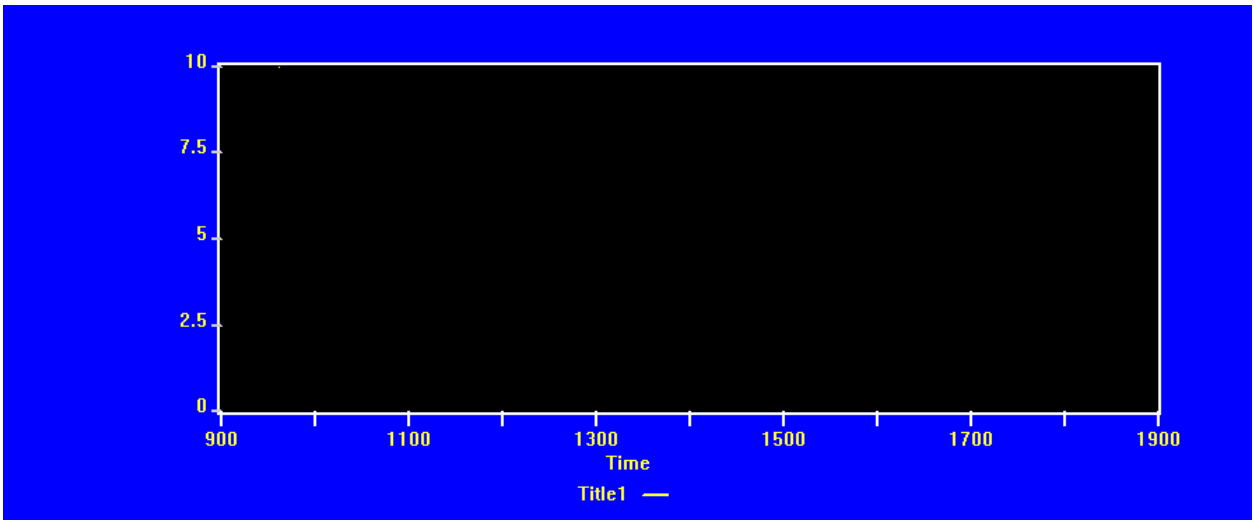


Figure: 5Form with filled parameters

After this, select the entry that appears , click “ Plot ”, and then click “ OK ”



A blue window appears with the designated coordinate system.



After this press Command => Retranslate . A diagram will appear in a blue window.

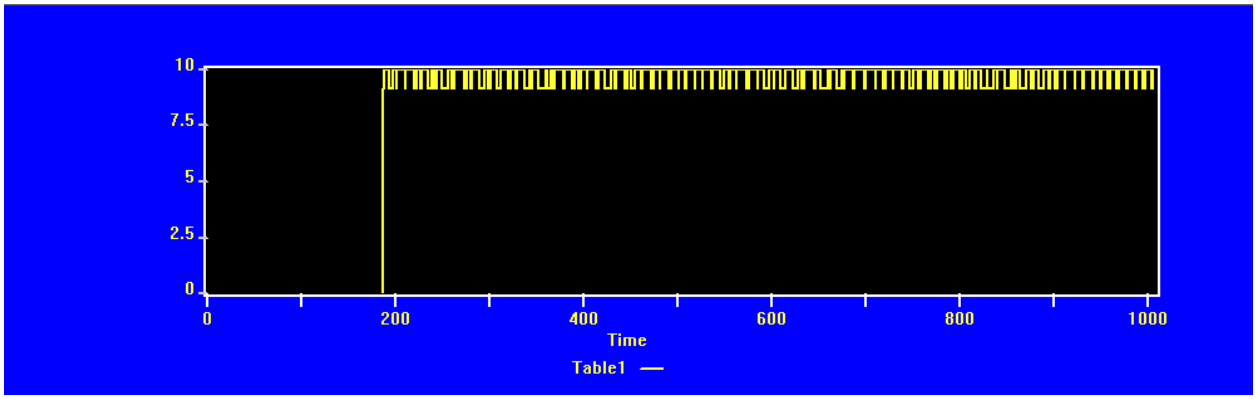


Figure 2.2. Queue load versus time

Window -> Simulation from the toolbar. Window Table Window . In the window that appears, click OK . The program creates a diagram that shows the relationship between

the number of transactions (packets) and the packet delay time in the queue. The vertical axis shows the number of transactions (packets), and the horizontal axis shows the packet wait time in the queue.

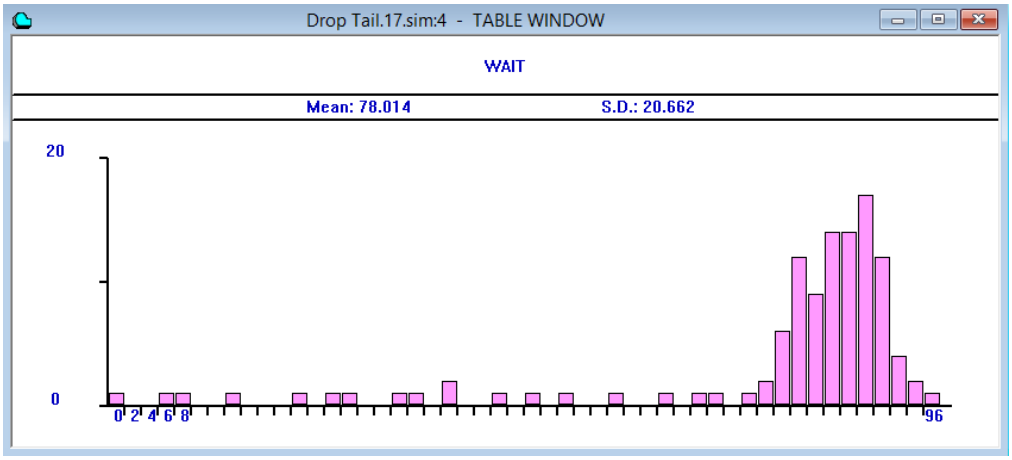


Figure 2.3. Table of packet waiting times in the queue

Task 2. Random early detection (RED) algorithm

Launch the GPSS application . To start working with algorithms, select *Open in the control panel* and select the document with the **RED algorithm** . The program will open the document with the selected algorithm:

Code listing of the RED algorithm model

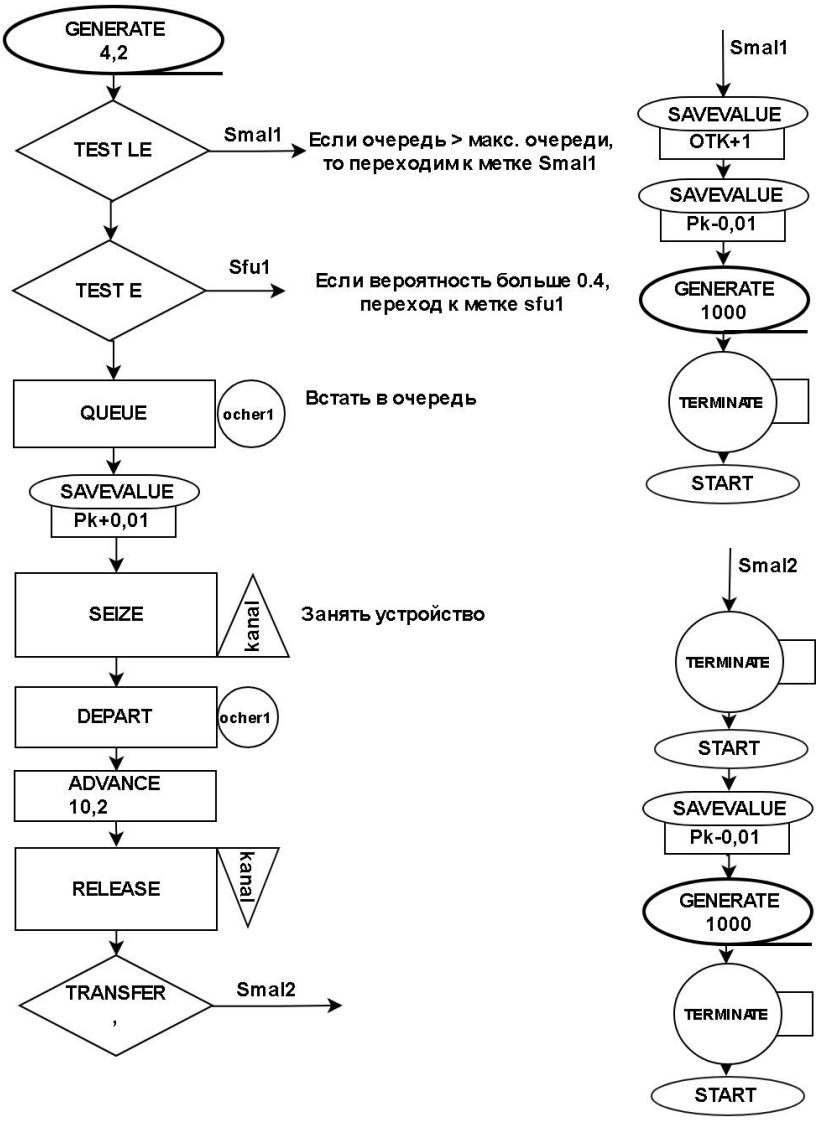
```
INITIAL        X$Pk,0
Wait           QTABLE            ocher1.0, 2.50
MaxOcher       EQU               8
MinOchre       EQU               2
    GENERATE   4 .2
    TEST L     Q$ocher1,MaxOcher,narrow1
    TEST L     Pk,0.4,sfu1
sfu1           TRANSFER0.5,smal1
    QUEUE      ocher1
    SAVEVALUE                    Pk+,0.1
    SEIZE      channel
    DEPARTMENT                   ocher1
    ADVANCE    10 .2
    RELEASE    channel
    TRANSFER   , narrow2
smal1          SAVEVALUEotk+,1
    TEST LPk,1,reset1
reset1         SAVEVALUEPk,1
smal2          TERMINATE 0
    SAVEVALUE                    Pk - ,0.1
    GENERATE1000
```

```
TERMINATE 1
START     1
```

Description of the program code

1. INITIAL block sets the probability variable Pk to 0.
2. Wait Block QTABLE creates a table ocher 1 of the waiting time in the packet queue.
3. EQU sets the MaxOcher variable to 8 and the MinOcher variable to 2.
4. The Generate block generates transactions.
5. TEST Block L compares two values. If the queue ocher 1 is less than the maximum queue MaxOcher , the transaction proceeds. Otherwise, it moves to the label small 1, where the SAVEVALUE block increments the value of dropped packets by 1. The packet then moves to the TERMINATE block , which destroys it.
6. Next block TEST L compares the value of the variable Pk with the set probability value, if Pk > 0.4, then the TRANSFER block with a probability of 0.5 transfers the transaction to the small 1 label, where the SAVEVALUE block increases the value of discarded packets by 1 and then the packet goes to the TERMINATE block , which destroys it.
7. The QUEUE block places the packet in queue ocher 1 for subsequent transmission over the communication channel.
8. SEIZE block simulates the preparation of a packet for transmission.
9. DEPART block sends a packet to the communication channel.
10. ADVANCE block simulates the processing (transmission) of a packet.
11. RELEASE releases the channel.

Algorithm flow chart



Select Command -> Create from the control panel. Simulation . The program creates a report. This report reflects all the information about the test performed. The program's output will look something like this:

Results of the model execution

SAVEVALUE	RETRY	VALUE
PK	0	1.000
OTK	0	245.000

FACILITY	ENTRIES	UTIL.	AVE. TIME	AVAIL.	OWNER	PEND	INTER	RETRY	DELAY
KANAL	100	0.995	9.946	1	239	0	0	0	6

QUEUE	MAX	CONT.	ENTRY	ENTRY(0)	AVE.CONT.	AVE.TIME	AVE.(-0)	RETRY
OCHER1	8	6	106	1	6.083	57.386	57.932	0

TABLE	MEAN	STD.DEV.	RANGE	RETRY	FREQUENCY	CUM.%
WAIT	59.047	18.014		0		

Figure 2.4. Results of the report of the developed model

From this report we obtained the following results *:*

1. Number of dropped packets: 245;
2. Number of packets passed: 141;

3. Channel load factor: 0.994;
4. Average package service time: 7.047;
5. Maximum queue length: 10;
6. Average queue length: 9,050;
7. Average queue time: 60.332.

After the report has been created, select Window -> Simulation Window -> Plot Window . In the window that appears, repeat the steps described for the first one, it will light up with the same parameters (Time Range , Max Value …)

Figure 2.5. Queue load versus time

Window -> Simulation from the toolbar. Window Table Window . In the window that appears, click OK . The program creates a diagram that shows the relationship between the number of transactions (packets) and the packet delay time in the queue. The vertical axis shows the number of transactions (packets), and the horizontal axis shows the packet wait time in the queue.

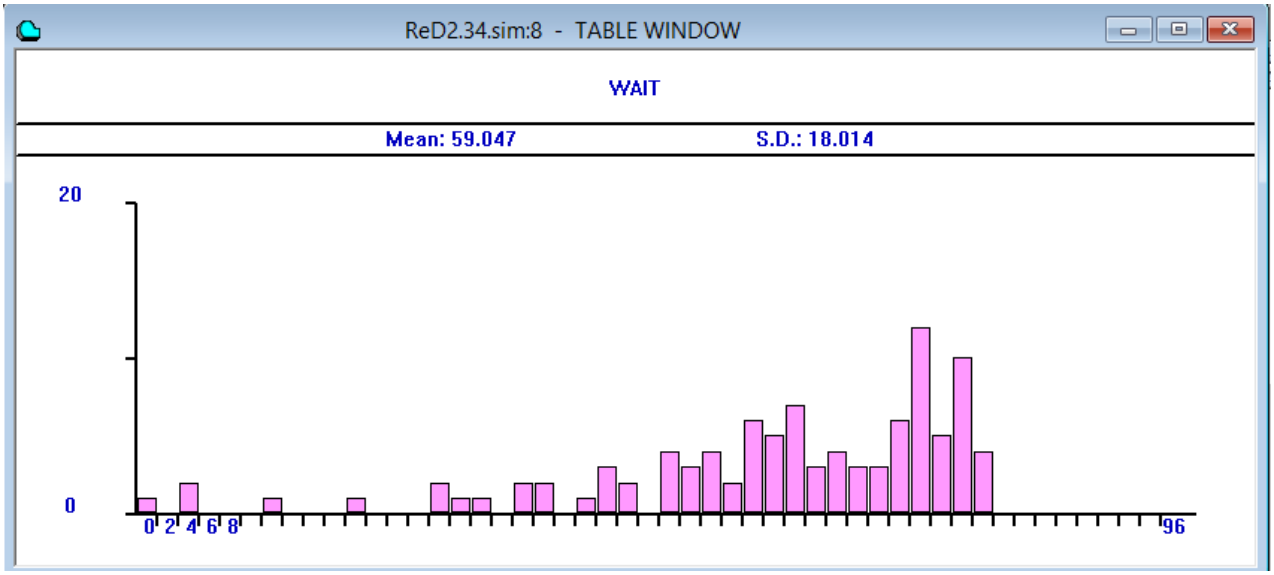


Figure 2.6. Table of packet waiting times in the queue

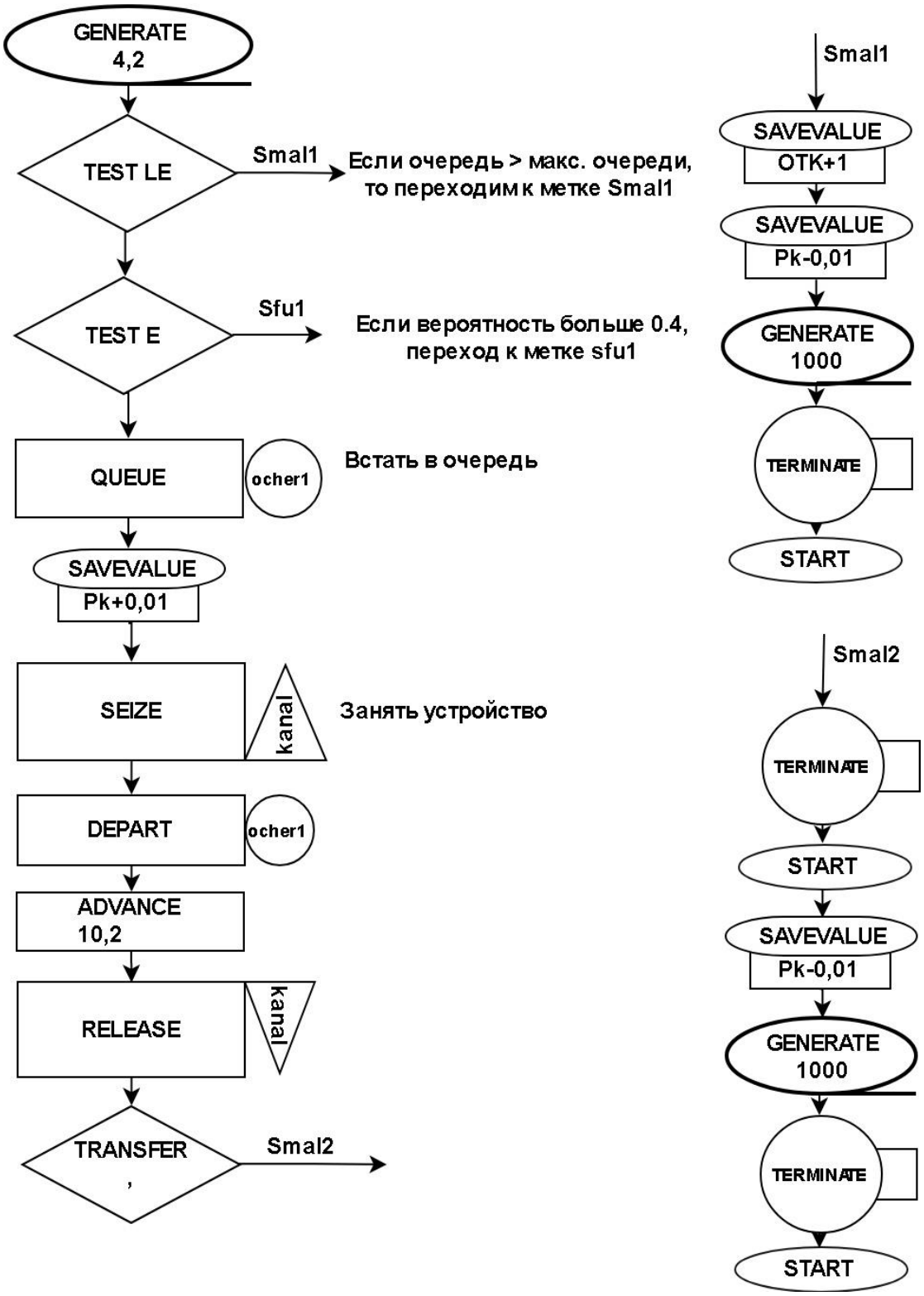
Task 3. RED In & Out (RiO) Algorithm

Launch the GPSS application . To start working with algorithms, select *Open in the control panel and select the* **RiO** algorithm document . The program will open the document with the selected algorithm:

Code listing of the RiO algorithm model

```
INITIAL                         X$Pk,0
Wait                            QTABLEocher1, 0,2,50
MaxOcher                        EQU    8
MinOcher                        EQU    2
              GENERATE 4,2,,,1
              TEST LQ$ocher1,MaxOcher,smal1
              TEST LPk,0.4,sfu1
sfu1          PRIORITY0
              TEST EPR,0,smal3
smal3                           TRANSFER0.5,smal1
              QUEUEocher1
              SAVEVALUEPk+,0.1
              SEIZEkanal
              DEPARTocher1
              ADVANCE10,2
              RELEASEkanal
              TRANSFER,smal2
smal1                           SAVEVALUEotk+,1
              TEST LPk,1,reset1
reset1                          SAVEVALUEPk,1
smal2                           TERMINATE 0
              SAVEVALUEPk-,0.1
              GENERATE1000
              TERMINATE         1
              START             1
```

Algorithm flow chart



Select Command -> Create from the control panel. Simulation . The program creates a report. This report reflects all the information about the test performed. The program's output will look something like this:

Results of the model execution

```
SAVEVALUE                    RETRY        VALUE
 PK                            0           1.000
 OTK                           0         146.000

FACILITY        ENTRIES  UTIL.   AVE. TIME AVAIL. OWNER PEND INTER RETRY DELAY
 KANAL              100   0.995       9.946  1      239    0     0     0      6

QUEUE             MAX CONT. ENTRY ENTRY(0) AVE.CONT. AVE.TIME   AVE.(-0) RETRY
 OCHER1             8    6    106      1     6.083     57.386     57.932   0

TABLE             MEAN    STD.DEV.       RANGE           RETRY FREQUENCY CUM.%
 WAIT            59.047   18.014                           0
```

Figure 2.7. Results of the report of the developed model

From this report we obtained the following results *:*

1. Number of dropped packets: 146;
2. Number of packets passed: 141;
3. Channel load factor: 0.994;
4. Average package service time: 7.047;
5. Maximum queue length: 10;
6. Average queue length: 9,050;
7. Average queue time: 60.332.

After the report has been created, select Window -> Simulation Window -> Plot Window . In the window that appears, repeat the steps described for the first one, it will light up with the same parameters (Time Range , Max Value …)

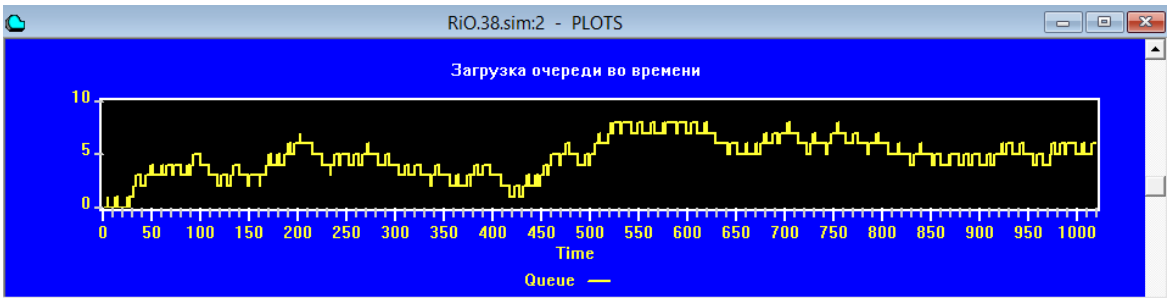


Figure 2.8. Queue load versus time

Window -> Simulation from the toolbar. Window Table Window . In the window that appears, click OK . The program creates a diagram that shows the relationship between the number of transactions (packets) and the packet delay time in the queue. The vertical axis shows the number of transactions (packets), and the horizontal axis shows the packet wait time in the queue.

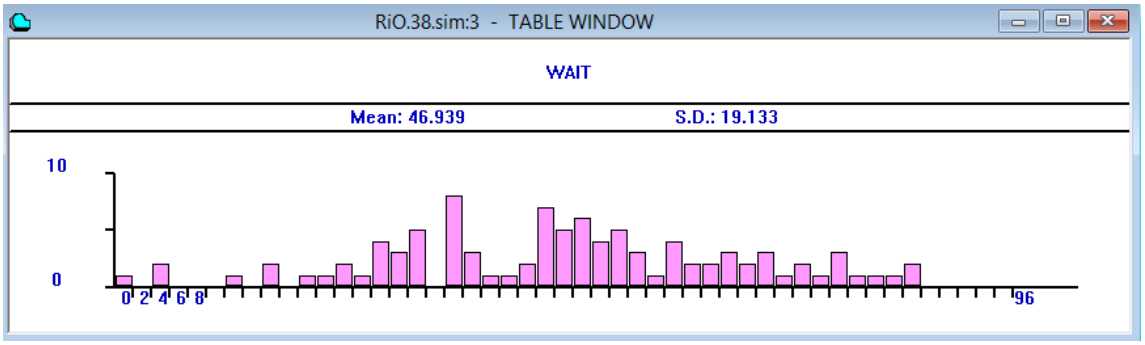


Figure 2.9. Table of packet waiting times in the queue

Conclusion: This work explored the principles of GPSS program algorithms . This work also provided skills in using GPSS .

Practical lesson #2

Subject : **Development And simulation study models element ASOIU based on the GPSS platform World**

C e l ь r A b O T y: receiving dependencies indicators quality ASOIU element from external influences.

Educational questions:

1.Development formalized models element ASOIU. 2. Development of a software model of the ASOIU element .
3.Study software models element ASOIU. 4. Analysis of output statistics.

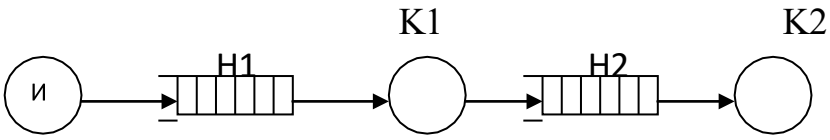
Exercise

Formalized model The ASOIU element is represented by a two-phase QS.

Applications from channel transmissions data are arriving into the system element through 20 ± 10 mls. and after preliminary processing for 15 ± 15 mls, they are sent for service to within 20 ± 5 mls. Build a model operation of this element of the ASOIU in flow 4-x hours. Get statistical data on application queues.

1. Development Q- circuits

The Q-circuit consists of a source, a channel and a first-phase accumulator . A channel and a second-phase accumulator.



Source AND imitates admission applications, storage devices H1 and H2 are used to store the service queue. Channel K1 serves for preliminary processing of the application, K2 – subsequent processing of applications.

IN scheme channels connected consistently, Means, has place two-phase single-channel Q-circuit.

2. *Development programs on language GPSS/PC*

```
10          SIMULATE                    start modeling
20          GENERATE     20.10          admission applications
29          QUEUE        JOB           class queues
30          ADVANCE      15.15          preliminary processing
```

```
40          SEIZE        IC
49          DEPART       JOB            liberation queues JOB
49          QUEUE        JOB2           class queues
50          ADVANCE      20.5           processing in IS
60          RELEASE      IC             exit applications
69          DEPART       JOB2           liberation queues JOB2
70          TERMINATE                    care from maintenance
80          GENERATE     1440           timer
90          TERMINATE    1
100         START        1
110         END
```

3.Study software models, analysis day off statistics .

We are exploring day off statistics of this tasks, at given simulation conditions.

```
 GPSS/PC Report file REPORT.GPS.  (V 2, # 39560)  03-01-
2001 16:56:10   page 1
 START_TIME   END_TIME  BLOCKS    FACILITIES  STORAGES FREE_MEMORY

     0         1440    11          1         0       18016

 LINE    LOC      BLOCK_TYPE    ENTRY_COUNT   CURRENT_COUNT  RETRY
  20     1         GENERATE      70             0            0
  29     2         QUEUE         70             0            0
  30     3         ADVANCE       70             1            0
  40     4         SEIZE         69             0            0
  49     5         QUEUE         69             0            0
  50     6         ADVANCE       69             1            0
  60     7         RELEASE       68             0            0
  69     8         DEPART        68             0            0
  70     9         TERMINATE     68             0            0
  80     10        GENERATE      1              0            0
  90     11        TERMINATE     1              0            0


FACILITY  ENTRIES  UTIL.   AVE._TIME AVAILABLE  OWNER PEND INTER RETRY DELAY

 IC      69   0.919  19.19     1      70    0  0     0    0


QUEUE   MAX  CONT. ENTRIES ENTRIES(0) AVE.CONT. AVE.TIME  AVE.(-0) RETRY
 JOB   70    70     70      0       34.38  707.19  707.19  0
 JOB2  1     1      69      0        0.92   19.19  19.19   0
```

Statistics by device:

- probability employment devices equal 0.919;
- average time employment devices one message equals 19.19;

- the number of messages that have occupied the device since the start of the program is 69;

Statistics By queues:

- maximum content queues JOB before K1 - 70 applications ;
- average time, conducted V queues JOB-707,19 mls;
- current content queues JOB V at the end period modeling –70;
- maximum content queues JOB2 before K2 - 1 bid ;
- average time, conducted V queues JOB2-0.92 mls;
- current content queues JOB2 V at the end period modeling –1;

As can be seen from Table 1, the higher the intensity of incoming requests, the greater the average time spent in queues taking into account all entries and the lower the probability, respectively. occupancy of the simulated system. For more efficient operation of the IS, the optimal time for requests to arrive from the PD channel to the IS is 10 ± 10 mls.

From the data in Table 2 it is evident that with an increase in the time of servicing a request in the second phase channel, the probability of device occupancy reaches a maximum and is equal to 0.972, and since for more efficient operation of this system it is desirable to reduce total time servicing applications in IS, then the optimal intensity equal service 25 ± 5 mls.

Average time spent in queues With taking into account all inputs, mls		Application volume V system, mls	Maximum queue contents		Probability of employment IS
JOB	JOB2		JOB	JOB2	
707.19	19.19	20 ± 10	70	1	0.919
718,58	19,60	10±10	144	1	0,979
717,97	19,47	10±5	149	1	0,973
703,57	19,07	15±5	96	1	0,966
723,36	19,80	20±5	74	1	0,962
704,46	19,79	25 ± 5	59	1	0.797
713.81	19.77	30 ± 5	48	1	0.659
722.51	20.49	35 ± 5	41	1	0.583
722.17	19.97	40 ± 5	35	1	0.485

Probability employment IS	Time service , mls
0.919	20 ± 5
0.484	10 ± 5
0.480	10 ± 10
0.705	15 ± 5
0.969	20 ± 10
0.972	25 ± 5
0.972	30 ± 5
0.972	35 ± 5
0.972	40 ± 10
0.215	5 ± 5

Order execution work

1. Review the guidelines for completing this laboratory work.
2. Get option tasks.
3. Compose program on language GPSS/PC.
4. Conduct imitation experiments on Personal computer.
5. Compose report.

Report O work must contain:
- exercise And original data By given option laboratory work;
- Q-circuit tasks And text programs;
- final results And conclusions By results modeling.

Options tasks

1. Signals from the sensors arrive at the channel input at time intervals of 10±5 μs. In the channel they are pre-processed for 10±3 μs. They are then sent to a minicomputer for processing, where the processing time is 33 μs. Simulate the processing of 90 signals.

2. The data transmission system receives packets from subscribers with time intervals between them 7-13 ms. Packet transmission takes 10 ms. Simulate the information exchange. in the system data transfer within 1 minute.

3. The computing center accepts tasks for processing that arrive within 20±5 minutes. Then they are loading in the computer and preliminarily are being processed V flow 10-20 min. And are completed in 10 minutes. Simulate the computer's operation in 25 hours. In a digital information transmission system, speech is transmitted in digital form. Speech packets are transmitted through a transit channel and are stored in a storage device. before the channel by 5 milliseconds. The packet transmission time over the channel is 5 milliseconds. Packets arrive every 6 ± 3 milliseconds. Simulate 10 seconds of system operation.

4. Simulate the process of processing 100 applications, the receipt of which obeys uniform law With interval 8±2 units of time, A processing - uniform law with average time 5±3 units"

5. Two streams of requests are received for processing: the first with an interval of 10±1 mls, the second with 25±2 mls. The second stream interrupts the processing of the first. Processing time applications first flow 7±3 mls, second 15±1 mls. Simulate the process of processing 50 applications.

6. Build a program for a model of the process of passing 70 parts arriving at time intervals of 12±2 units and processed by one worker in five consecutive operations, time execution which distributed V interval 2±1 units of time. The distribution of all times is uniform.

7.On processing arrives two flow applications: first With The first stream has an interval of 10±1 mls, the second has an interval of 25±2 mls. The processing time for the first stream is 7±3 mls, the second 15±1 mls. The streams are processed in parallel. Simulate the processing of 50 requests.

8. Model process passages 100 applications, admission which obey a uniform law with an interval of 8±2
units time, A processing is produced parallel two devices with an average time of 5±3 units.

9. Simulate the process of passing 100 messages, the arrival of which obeys a uniform law with an interval of 18±5 time units. Messages can be processed on one of two devices; on the first with time 15±5 units, on second -17±10 . Moreover It is preferable to process on the first device.

10. Simulate the process of passing 100 messages, the arrival of which obeys a uniform law with an interval of 18±5 time units. Messages can be processed on one of two devices; on the first with time 15±5 units, on second -17±10 . Moreover It is preferable to process on the first device.

11. Signals from the sensors arrive at the channel input at time intervals of 10±5 μs. In the channel they are pre-processed for 10±3 μs. They are then sent to a minicomputer for processing, where the processing time is 33 μs. Simulate the processing of 90 signals.

12. The data transmission system receives packets from subscribers with time intervals between them 7-13 ms. Packet transmission takes 10 ms. Simulate the information exchange. in the system data transfer within 1 minute.

13. The computing center accepts tasks for processing that arrive within 20±5 minutes. Then they are loading in the computer and preliminarily are being processed V flow 10-20 min. And are completed in 10 minutes. Simulate the computer's operation in 25 hours. In a digital information transmission system, speech is transmitted in digital form. Speech packets are transmitted through a transit channel and are stored in a storage device. before the channel by 5 milliseconds. The packet transmission time over the channel is 5 milliseconds. Packets arrive every 6 ± 3 milliseconds. Simulate 10 seconds of system operation.

14. Simulate the process of processing 100 applications, the receipt of which obeys uniform law With interval 8±2 units of time, A processing - uniform law with average time 5±3 units"

15. Two streams of requests are received for processing: the first with an interval of 10±1 mls, the second with 25±2 mls. The second stream interrupts the processing of the first. Processing time applications first flow 7±3 mls, second 15±1 mls. Simulate

the process of processing 50 applications.
16. Build a program for a model of the process of passing 70 parts arriving at time intervals of 12±2 units and processed by one worker in five consecutive operations, time execution which distributed V interval 2±1 units of time. The distribution of all times is uniform.
17.On processing arrives two flow applications: first With The first stream has an interval of 10±1 mls, the second has an interval of 25±2 mls. The processing time for the first stream is 7±3 mls, the second 15±1 mls. The streams are processed in parallel. Simulate the processing of 50 requests.
18. Model process passages 100 applications, admission which obey a uniform law with an interval of 8±2
units time, A processing is produced parallel two devices with an average time of 5±3 units.
19. Simulate the process of passing 100 messages, the arrival of which obeys a uniform law with an interval of 18±5 time units. Messages can be processed on one of two devices; on the first with time 15±5 units, on second -17±10 . Moreover It is preferable to process on the first device.
20. Simulate the process of passing 100 messages, the arrival of which obeys a uniform law with an interval of 18±5 time units. Messages can be processed on one of two devices; on the first with time 15±5 units, on second -17±10 . Moreover It is preferable to process on the first device.

Practical lesson #3

Development of a simulation model of segmentation Super Stack Load Concentrator || Switch 1000 Mbps ‖

Subject :
C e l ь r A b O T y: receiving dependencies indicators quality concentrator from the

intensity of the input load

Educational questions

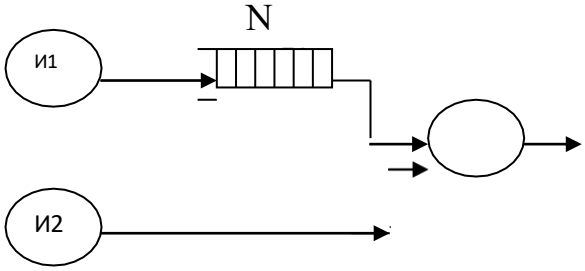
1.Development formalized models commuting hub. 2.Development of a software model of a switching hub.
3.Study software models commuting concentrator. 4.Analysis of output statistics.

Exercise

Two workstations are connected radially to a segmentation hub . Service requests from the first station arrive at intervals of 20 ± 10 μs, and from the second at intervals of 60 ± 20 μs. The latter have the highest priority. Service time is subject to exponential law. law and is equal on average to 15 μs for the first station and 25 μs for the second. Simulate the work switch, having studied the statistics queues for 2 hours.

1. Development Q- circuits

Q-scheme includes two source, storage device And channel , That There is a single-phase.



Sources I1 And I2 imitate admission applications. There is accumulator H for applications originating from the first source, since applications the second source are served out of turn. Channel K is used for servicing incoming requests from both sources.

2. Development programs on language GPSS/PC

```
10          SIMULATE                 start modeling
20 EXP      FUNCTION     RN1,C6      description functions
0.0/.1,.1/.2,.2/.5,.69/.8,1.6/1.8    parameters functions
30          GENERATE     20.10      coming applications from
                                    first
                                    source
40          QUEUE        LIN        inclusion V queue
50          SEIZE        REG
60          DEPART       LIN        exit from queues
70          ADVANCE      15,FN$EXP  service applications first
                                    source
80          RELEASE      REG
90          TERMINATE               care applications
100         GENERATE     60.20,,,1   coming applications from
                                     second
```

```
                                        source
110         QUEUE        LIN
120         SEIZE        REG
130         DEPART       LIN
140         ADVANCE      25,FN$EXP   service applications
                                     from
                         second source
150         RELEASE      REG
160         TERMINATE
170         GENERATE     720         timer
180         TERMINATE    1
190         START        1
200         END
```

3.Study software models, analysis day off statistics .

Let's analyze day off statistics higher simulated tasks, under given simulation conditions.

```
GPSS/PC Report file REPORT.GPS.  (V 2, # 39560)  03-02-
2001 16:41:30   page 1

START_TIME END_TIME  BLOCKS  FACILITIES  STORAGES  FREE_MEMORY
   0         720      16        1          0       15712

LINE    LOC   BLOCK_TYPE  ENTRY_COUNT CURRENT_COUNT   RETRY
30      1       GENERATE      33          0           0
40      2       QUEUE         33          15          0
50      3       SEIZE         18          0           0
60      4       DEPART        18          0           0
70      5       ADVANCE       18          0           0
80      6       RELEASE       18          0           0
90      7       TERMINATE     18          0           0
100     8       GENERATE      11          0           0
110     9       QUEUE         11          2           0
120     10      SEIZE         9           0           0
130     11      DEPART        9           0           0
140     12      ADVANCE       9           1           0
150     13      RELEASE       8           0           0
160     14      TERMINATE     8           0           0
170     15      GENERATE      1           0           0
180     16      TERMINATE     1           0           0


FACILITY ENTRIES  UTIL.  AVE._TIME AVAILABLE OWNER PEND INTER RETRY DELAY

 REG     27  0.906  24.19     1     33    0  0     0    17

QUEUE MAX CONT. ENTRIES ENTRIES(0) AVE.CONT. AVE.TIME  AVE.(-0) RETRY
```

```
LIN  17  17   44     4       7.34   120.11 132.12   0
```

Statistics by device:
- probability employment devices equal 0.906;
- average time employment devices one message equals 24.19;
- the number of messages that have occupied the device since the start of the program is 27;

Statistics By queues:
- maximum content queues - 17 applications ;
- average time, conducted V queues-120.11 sec.;
- current contents of the JOB queue at the end of the period simulations -17. Results of simulations experiments are being drawn up V view tables or graphics.

Analyzing data tables 2.1. we do next conclusions :
- the higher the intensity of the incoming request being processed out of turn, the higher the maximum content of the queue, the time one request spends in the queue and also the probability of being busy;
- the lower the intensity of incoming applications from the first source, the more maximum queue content and time spent in the queue.

For the most efficient operation of the system, we select I1=20±10 sec., I2=60±15sec.

Table 2.1.

Average time spent in queue With taking into account all inputs, s.	Maximum queue content	Application inflow rate, s		Probability of employment
		I1	I2	
120.11	17	20 ± 10	60 ± 20	0.906
192.42	27	20 ± 5	60 ± 20	0.927
225.03	54	10 ± 5	80 ± 5	0.977
85.60	17	20±5	60±10	0,815
201,26	57	10±5	70±10	0,975
126,79	23	20±10	60±15	0,913
61,07	9	35±5	70±10	0,730

Order execution work

1. Review the guidelines for completing this laboratory work.

2. Get option tasks.
3. Create a program in GPSS/PC language. 4. Conduct imitation experiments on Personal computer.
5. Compose report.

Report O work must contain:

- exercise And original data By given option laboratory work;
- Q-circuit tasks And text programs;
- final results And conclusions By results modeling.

Options tasks

1. The data transmission highway consists of two channels (primary and backup) and a common storage device. During normal operation, messages are transmitted via the primary channel in 7 ± 3 s. In the primary channel failures occur at intervals time 200 ± 35 sec. If failures occur during transmission, then within 2 sec a backup channel is launched, which transmits interrupted message from the very beginning. Restoring the main channel takes 23 ± 7 s. After restoration, the backup channel is switched off and the main channel continues operation from the next messages. Messages arrive after 9 ± 4 seconds and remain in the storage until the transmission is complete. In the event of a failure, the transmitted message is retransmitted via a backup channel. Simulate data transmission for 1 hour. Time is subject to an exponential law.
2. The computing center accepts two types of tasks for processing: A and B. Based on the availability of RAM, class C tasks monopolize the computer. Class A tasks arrive after 20 ± 5 minutes, and class B-20 ± 10 min and require 30 min and 25 min respectively for execution and subject to exponential law. Simulate the work Computer in 20 hours.
3. The data transmission system receives packets from two subscribers with time intervals between them 7-13 ms. Moreover, packets from the first subscriber have priority. Packet transmission takes 10 ms. Simulate the exchange of information in a data transmission system within 1 minute. The packet arrival times are distributed exponentially .
4. The computing center accepts tasks from three sources for processing, which arrive 20 ± 5 minutes from the first source and 30 ± 10 minutes from the second and third sources. Tasks from the second source have higher priority. Then They are loading V computer And

pre-processed within 10-20 minutes and are completed in 10 minutes. Simulate the operation of a computer for 25 hours.

5. In a digital information transmission system, speech is transmitted in digital form. Speech packets are transmitted through a transit channel, are delayed in the drive before the channel by 5 milliseconds. The packet transmission time over the channel is 5 milliseconds and is distributed exponentially. Packets arrive from two sources through 6 $\pm$ 3 mls and is subject to a uniform law. Simulate 10 seconds of system operation.
6. Simulate the process of passing 100 applications, the receipt of which is subject to a uniform law with an interval of 8 $\pm$ 2 time units, and processing is exponential law with an average time of 5 $\pm$ 3 units.
7. There are two streams of applications being processed: the first with an interval of 10 $\pm$ 1 mls, the second with 25 $\pm$ 2 mls. The second flow is interrupted processing of the first. Processing time for applications of the first stream distributed evenly and amounts to 7 $\pm$ 3 mls, and the second is exponentially distributed and is equal to 15 $\pm$ 1 mls. Simulate the process of processing 50 applications.
8. Build a program to model the process of passing 70 parts coming in from two identical sources with time intervals of 12 $\pm$ 2 units and processed by one worker in five successive operations, the execution times of which are subject to an exponential law in the range of 2 $\pm$ 1 unit.
9. Two streams of applications are received for processing: the first is subject to the exponential law and is equal to 20 $\pm$ 5 mls, the second is distributed evenly in the interval 25 $\pm$ 2 mls. The processing time for the first stream of requests is 7 $\pm$ 3 mls, for the second 15 $\pm$ 1 mls. Moreover, requests for the second stream have priority. Simulate the processing of 50 requests.

Practical lesson No. 4

Topic : Modeling And study of quality indicators of formalized single-processor computer models

C e l ь r A b O T ы : obtaining dependencies of quality indicators for processing tasks on a single-processor computer from external load

Educational questions:

1.Development formalized models single-processor Computer. 2. Development of a software model for a single-processor COMPUTER.
3.Study software models single-processor COMPUTER.
4.4.Analysis of output statistics.

Exercise

The RAM of a single-processor computer is divided into three Sections numbered 0, 1, and 2. Each section contains one program. The lower the section number, the higher the program's priority. Programs are executed based on user requests received at random times.

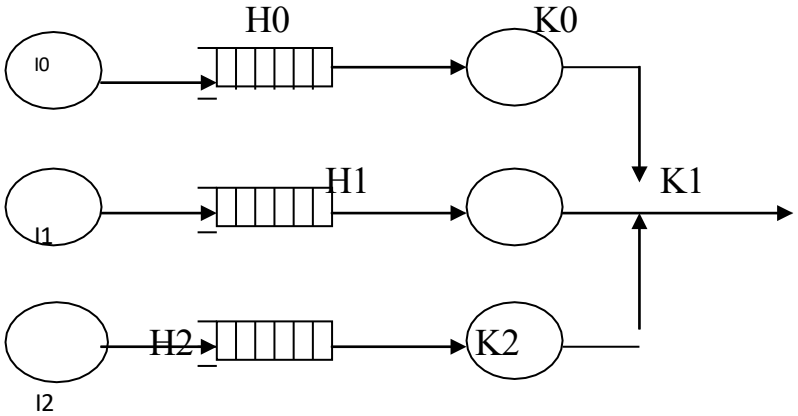
The program in section zero is called at intervals of 10 ± 8 s, and its execution time, depending on the data being processed, is 3 ± 2 s. The program in section one is called every 2 minutes and executes for 30 ± 15 s. Half an hour after requests begin arriving in sections zero and one, requests begin arriving in section two at intervals of 5 ± 4 minutes and are processed for 1 minute.

In case of conflict situations, when upon receipt of one requirement the processor fulfills another requirement, the absolute priority discipline is used.

Simulate 1 hour of the described process. During the simulation, count the number of requests of each type processed.

1. Development Q- circuits

Q - the scheme includes three source, three storage device And three channels. This scheme is single-phase and three-channel.



The drives simulate partitions of a computer's RAM; their capacity is equal to one, since each partition stores one program. Sources I0, I1, and I2 simulate the incoming programs from RAM, A their intensity respectively equal λ 0=10 ± 8 With, λ 1=120 With,
λ 2=300 ± 240 s. There are three channels for processing program data for each section. Intensity processing channels respectively equal to:
μ 0=3 ± 2 With, μ 1=30 ± 15 With, μ 2 = 120 With.

2. Development programs on language GPSS/PC

```
10          SIMULATE

* model zero section
```

```
20          GENERATE     10.8,,,2
30          SAVEVALUE    1+,1           count requirements
40          PREEMPT      PROC,PR        capture processor
50          ADVANCED     3.2
60          RETURN       PROC             liberation processor
70          SAVEVALUE    2+,1
80        TERMINATE
* model  first section
90          GENERATE     120,,,,2
100         SAVEVALUE    3+,1
110         PREEMPT      PROC,PR
120         ADVANCED     30.15
130         RETURN       PROC
140         SAVEVALUE    4+,1
150       TERMINATE
* model  second section
160         GENERATE     300,240,1800
170         SAVEVALUE    5+,1
180         PREEMPT      PROC,PR
190         ADVANCE      60
200         RETURN       PROC
210         SAVEVALUE    6+.1
220       TERMINATE
* timer
230         GENERATE     3600
240         TERMINATE    1
250         START        1
260         END
```

3.Study software models, analysis day off statistics .

Let us analyze the output statistics of the above simulated problem, under the given simulation conditions.

For time modeling was processed 390 programs, CPU
It was "captured" 398 times. However, the processor was busy for only 64.2% of the simulation period. The average time a single program spent occupied by the processor was 5.81 seconds.

For zero section:

- number received requirements equals 361 ;
- number served requirements 361. For

the first section:

- number received requirements equals 30 ;
- number served requirements 29. For

the second section:

- number received requirements equals 7 ;
- number served requirements 6.

GPSS/PC Report file REPORT.GPS. (V 2, # 39560) 03-05-2001 18:28:58 page 1

START_TIME	END_TIME	BLOCKS	FACILITIES	STORAGES	FREE_MEMORY
0	3600	23	1	0	16320

LINE	LOC	BLOCK_TYPE	ENTRY_COUNT	CURRENT_COUNT	RETRY
20	1	GENERATE	361	0	0
30	2	SAVEVALUE	361	0	0
40	3	PREEMPT	361	0	0
50	4	ADVANCE	361	0	0
60	5	RETURN	361	0	0
70	6	SAVEVALUE	361	0	0
80	7	TERMINATE	361	0	0
90	8	GENERATE	30	0	0
100	9	SAVEVALUE	30	0	0
110	10	PREEMPT	30	0	0
120	11	ADVANCE	30	1	0
130	12	RETURN	29	0	0
140	13	SAVEVALUE	29	0	0
150	14	TERMINATE	29	0	0
160	15	GENERATE	7	0	0
170	16	SAVEVALUE	7	0	0
180	17	PREEMPT	7	0	0
190	18	ADVANCE	7	1	0
200	19	RETURN	6	0	0
210	20	SAVEVALUE	6	0	0
220	21	TERMINATE	6	0	0
230	22	GENERATE	1	0	0
240	23	TERMINATE	1	0	0

FACILITY	ENTRIES	UNUSED	AVE._TIME	AVAILABLE	OWNER	PEND	INTER	RETRY	DELAY
PROC	398	0.642	5.81	1	390	0	1	0	0

SAVEVALUE	VALUE	RETRY
1	+361	0
2	+361	0
3	+30	0
4	+29	0
5	+7	0
6	+6	0

By running the model multiple times for different intensities of incoming requests and program processing times in RAM partitions, we will determine the dependencies:

- processor occupancy probabilities depending on the intensities of incoming requests;
- the probability of processor occupancy from the intensity of program processing in sections of RAM.

Let's summarize received data V tables (table 1. And Table 2.).

Table 1

CPU busy probability	arrival time from 0 section, With	Time of receipt of the request from 1st section, With	Time of receipt of the request from the 2nd section, With
0.642	10 ± 8	120	300 ± 240
0.986	5	60	150
0.306	20	240	600
0.459	10	240	600
0.603	10	120	600
0.746	10	120	150

From Table 4.1 shows that the maximum probability of processor occupancy is 0.986, but there will be a large number of failures. The optimal the solution to this problem is

- probability employment processor -0.746
- time receipts requirements from
  Section 0 of Article 10(c),
  from 1st -120 s,
  from 2nd 150 s.

At this optimal decision number requirements for the zero section:

- received equals 360 ;
- served - 359; for the

first section:

- received - 30 ;
- served - 29; for the

second section:

- received - 13;
- served - 12.

Table 2

CPU busy probability	Processing intensity requirements from 0 section, With	Processing intensity requirements from 1st section, With	Processing intensity requirements from 2nd section, With
0.642	3 ± 2	30 ± 15	60
0.480	3	10	50
0.871	6	20	120
0.991	10	20	120
0.996	20	20	120
0.996	20	30	120

The optimal probability of processor occupancy is 0.871, since with this solution to the problem and the probability of employment is relatively high and the failure rate is low.

Those:

- probability employment processor -0.871
- intensity processing requirements from
  Section 0, 6 c,
  from 1st -20
  from, from 2nd
  120 With.

At this decision number requirements for the zero section:

- received equals 369 ;
- served - 366; for the

first section:

- received - 30 ;
- served - 29; for the

second section:

- received - 8;
- served - 3.

Order execution work

1. Review the guidelines for completing this laboratory work.
2. Get option tasks.
3. Create a program in GPSS/PC language. 4. Conduct imitation experiments on Personal computer.
5. Compose report.

Report O work must contain:

- exercise And original data By given option laboratory work;

- Q-circuit tasks And text programs;
- final results And conclusions By results modeling.

Options tasks

1. In a specialized The computing system periodically executes three types of tasks, each characterized by priority levels: zero, first, and second. Each new task is launched after 50 ± 30 seconds. Once launched, a task requires 100 ± 50 seconds of processor time to complete, with higher-priority tasks interrupting lower-priority tasks. Simulate the system's operation for 3 hours.

2. The data transmission highway consists of two channels (primary and backup) and a common storage device. During normal operation, messages are transmitted via the primary channel in 9 ± 3 s. In the primary channel failures occur at intervals time 200 ± 50 s. If failures occur during transmission, then for 2 With is starting spare channel, which transmits interrupted message from the very beginning. Restoring the main channel takes 23 ± 7 s. After restoration, the backup channel is turned off and the main channel continues operating from the next messages. Messages arrive after 9 ± 4 s and remain in the storage until the transmission is complete. In the event of a failure, the transmitted message is retransmitted via a backup channel. Simulate data transmission for 1 hour. Time is subject to a uniform law. law

3. The computing center processes three classes of tasks: A, B and C. Based on priorities tasks of classes A and B can be solved simultaneously (they have the same priorities, the priority of tasks class WITH below). Tasks class A are arriving through 20 ± 5 min, class B- 20 ± 10 min And class WITH- through 30 ± 10 min And require For execution: A- 20 min
,B- 21 min and C - 28 min. Simulate the computer's operation for 10 hours. All processes are subject to the exponential law.

4.A stream of requests is received for processing at intervals of 10 ± 1 time units. Odd requests are processed on the first device with a time of 15 ± 2 units, and even requests are processed on the second device with a time of 17 ± 3 units. Simulate the system's operation when processing 100 requests.

5.Create a program the process of processing applications, the receipt of which obeys a uniform law with interval 9 ± 1 sec. Messages can be processed on one of two devices: on the first – with a time of 5 ± 3 sec, on the second – with a time of 7 ± 2 sec. Moreover, processing on the first device is preferable. Simulate the process of processing 75 requests.

6.Let us assume that under the conditions of the fifth option, applications are received for processing by the first device with a probability of 0.7 and by the second device with a probability of 0.3.

The receipt of applications is subject to the normal law. Simulate the operation of the system during 3 hours.

7. Two types of applications are received for processing. Applications of the first type every 10 ± 5 sec, the second every 30 ± 10 sec. In this case Requests of the second type are processed out of turn. The processing time is exponential and averages 8 seconds for requests of the first type and 12 seconds for requests of the second type. Simulate the operation of the facility for 2 hours.

8.Two types of requests arrive at the data center for processing. The arrival time of requests of the first type is distributed within the interval of 10 ± 5 minutes, requests of the second type - 5 ± 2 μινυτεσ. Τηε τιμε σπεντ ον σερϖιχινγ ισ 0.8 ± 3 and 5 ± 1 μινυτεσ, respectively . Requests of the first type are processed out of turn. Simulate the operation of the data center for 10 hours.

9. On processing are arriving two flow of applications With interval time 20 ± 5 sec. It takes time to pre-process the first flow of requests 4 ± 1 sec, and the second stream of applications 2 ± 1 sec. The actual processing of applications takes 7 ± 3 sec. Second-stream requests are processed out of turn during pre-processing. All processes are subject to uniform law. Simulate work systems V flow 7 hours.

10. The data transmission highway consists of two channels (primary and backup) and a common storage device. During normal operation, messages are transmitted via the primary channel in 7 ± 1 s. In the primary channel Failures occur every 500 seconds. If they occur during transmission, a backup channel is launched within 1 second, which transmits the interrupted message from the very beginning. Messages arrive within 10 ± 2 seconds and remain in the storage until the end of the transmission. In the event of a failure, the transmitted message is retransmitted via the backup channel. Simulate data transmission for 1 hour. Time is subject to a uniform law. law.

Practical lesson #5

Topic: Development and research of a model for distributing virtual resources of a data processing system

Questions

1. To study the features of resource provision of complex information systems, virtualization technologies.

2) Develop an analytical model for the problem of optimizing virtual resources of cloud environments.

3) Minimize the cost of virtual resources using the Solver add-in in MS Excel

1. FEATURES OF RESOURCE PROVISION OF COMPLEX INFORMATION AND COMPUTING SYSTEMS

The application of virtualization developments in complex computing systems is distinguished by the following features:

1. Affordable hardware costs due to the use of virtualization servers together with thin clients, allowing:
   - reduce the amount of disk space used many times over;
   - customers to purchase equipment at lower prices.
1. Significant reduction in power consumption. Thin clients consume less electricity when operating.
2. Nowadays, thin clients are much cheaper than before.
3. Thin clients can now be installed on older computers, meaning there is no need to use new, expensive PCs.
4. Using virtualization reduces the price of licensed software.
5. The time required for software maintenance is reduced.
6. Creating images on virtual machines indicates high protection against viruses.
7. Working with a virtual machine shows that the OS loads faster.

1.1. Development of the problem of optimizing resource provision of the temporary detention facility

Suppose that several computing processes of a single distributed application are running in a distributed system (a cluster of virtual machines) with a constantly changing workload. For simplicity, we will assume that each process runs on a separate node. The processes perform useful work in the background (giving priority to operating system processes and application processes of the node's user). The processes are synchronized at certain points, and during the synchronization step, each process performs its share of typical calculations proportional to the performance of its node. Suppose that for any virtual machine type F_i, where $i = 1, \ldots, n$, its technical characteristics are known, that is, the quantitative content of the assigned components in a single instance of a given virtual machine type. In this case, we can represent a matrix consisting of the characteristics of the virtual machine types:

$$\begin{array}{c} \\ N_1 \\ \vdots \\ N_m \end{array} \begin{array}{c} \begin{array}{ccc} F_1 & \ldots & F_n \end{array} \\ \begin{bmatrix} a_{1,1} & \cdots & a_{1,n} \\ \vdots & \ddots & \vdots \\ a_{m,1} & \cdots & a_{m,n} \end{bmatrix} \end{array} \quad (1)$$

The cells of this table form an m * n matrix , which will be called the virtual resource matrix. We then calculated the capacity distribution $x^T = (x_1, x_2, \ldots, x_n)$ for a specific time period for which the exact number of users is known. In other words, we plan to provide each user group with a session:

1) x_1 copies of VM type F_1;
1) x_2 copies of VM type F_2;
2) ……;
3) x_n instances of VM of type F_n.

It's easy to determine the RAM and storage size, as well as the microprocessor performance, that each user group will receive per session. Parameter $\#_1$ is located in this power distribution in the total number:

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \quad (2)$$

Because x_1 instances of VM type F_1, based on the matrix of virtual resources, contain $a_{11}x_2$ units of characteristics N_1. To this quantity is added the size of $a_{12}x_2$ characteristics N_1 from x_2 copies of VM type F_2 etc. The number of all other characteristics N_i in the compiled capacity distribution $x^T = (x_1, x_2, \ldots, x_n)$ *can also be calculated in the same way.* Let's assume that there are requirements that concern the provision of a certain quantity of each characteristic N_i, where $i = 1, \ldots, m$, to each group of users within a given time frame. For example, the total amount of allocated RAM should not be less than required. Let's express such requirements as a vector $b^T = (b_1, b_2, \ldots, b_m)$, the i component of which indicates the minimum required content of the characteristic N_i in the distribution of powers. It follows that the coordinates x_i vector x^T must satisfy the following system of constraints:

$$\begin{array}{c} a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \geq b_1, \\ a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \geq b_2, \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \geq b_m. \end{array} \quad (3)$$

From the statement of the problem it is clear that all variables $x_1, x_2, \ldots, x_n$ are positive. Based on this, the following inequalities are added to constraints (3):

$$\begin{array}{c} x_1 \geq 0, \\ x_2 \geq 0, \\ \ldots\ldots\ldots \\ x_n \geq 0. \end{array} \quad (4)$$

It is clear that any distribution of powers $x^T = (x_1, x_2, \ldots, x_n)$ must satisfy conditions (3) and (4). But there may be an infinite number of such capacity distributions, and therefore, to select one of them, a cost criterion is introduced – the price of the set. Let the cost of VM of type $F_1, F_2, \ldots, F_n$ *be equal to* $c_1, c_2, \ldots, c_n$, respectively . From this it follows that the cost of the general capacity distribution $x^T = (x_1, x_2, \ldots, x_n)$ can be written as a price function:

$$c_1x_1 + c_2x_2 + \ldots + c_nx_n \quad (5)$$

The final formulation of the virtual resource allocation problem: among all vectors $x^T = (x_1, x_2, \ldots, x_n)$, which satisfy constraints (3) and (4), it is necessary to select a vector for which expression (5) takes a minimum value. This completes the process of constructing the capacity allocation problem. The problem of finding the most efficient distribution of virtual resources is briefly expressed in the following matrix-vector form:

$$\begin{gathered} c^T x \to min, \\ A_x \geq b, \\ x \geq 0. \end{gathered} \tag{6}$$

where A *is an* $m \times n$ matrix ; b , c , and x are column vectors of the corresponding dimensions. Expressing the real-world problem in rigorous mathematical form allowed us to apply the full range of mathematical methods to its solution.

1.2. Excel Solver

The MS Excel "Solver" add-in allows you to solve a wide range of optimization problems. "Solver" in Excel allows you to quickly find optimal solutions to fairly complex models, not just linear ones, without knowledge of algorithms or lengthy, routine iterations.

"Solver" is part of a task block sometimes referred to as "what-if" analysis. The Solver procedure finds the optimal value for a formula contained in a cell, called the target cell. The procedure operates on a group of cells directly or indirectly related to the formula in the target cell. To achieve a specified result based on the formula contained in the target cell, the procedure modifies the values in the reference cells. Constraints are also applied to reduce the number of values used in the model. These constraints can reference other reference cells.

The solution search procedure can be used to determine the value of the influencing cell corresponding to the extremum of the dependent cell.

The MS Excel Solver add-in allows you to obtain a desired value in a specific cell, called the target cell, by changing the values of several reference cells. Additionally, when searching for a solution, you can specify additional conditions—imposing restrictions on changes to the reference cell parameters. Up to 200 reference cells can be specified.

To perform the Solver operation, use the "Tools - Solver" menu command. It may not be available in the Tools menu. In this case, select Add-ins from the Tools menu and select the desired checkbox in the list of enabled add-ins.

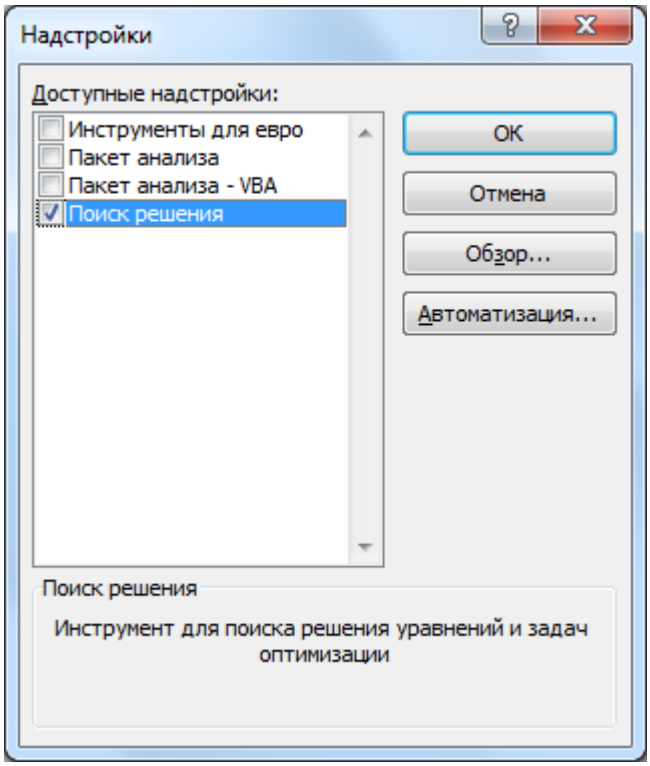


Figure 1. List of connected add-ons

Add-ins are specialized tools that extend Excel's computing capabilities. Since enabling add-ins increases the load on the computing system, it is recommended to enable only those necessary for the current work session.

To perform the "Solver" operation, you need to run the "Tools" - "Solver" command and set the solution parameter values in the "Solver" dialog box:

– the address of the target cell in which the value will be selected;

– optimality criterion (maximum or minimum value) or value to be found;

– addresses of the cells to be changed; the addresses of individual cells or ranges are separated by commas; the "Suggest" button is used to automatically select the cells that affect the target;

– constraints that must be taken into account when searching for a solution; to enter multiple constraints, use the "Add" button.

The result of performing the above actions can be seen in Figure 2:

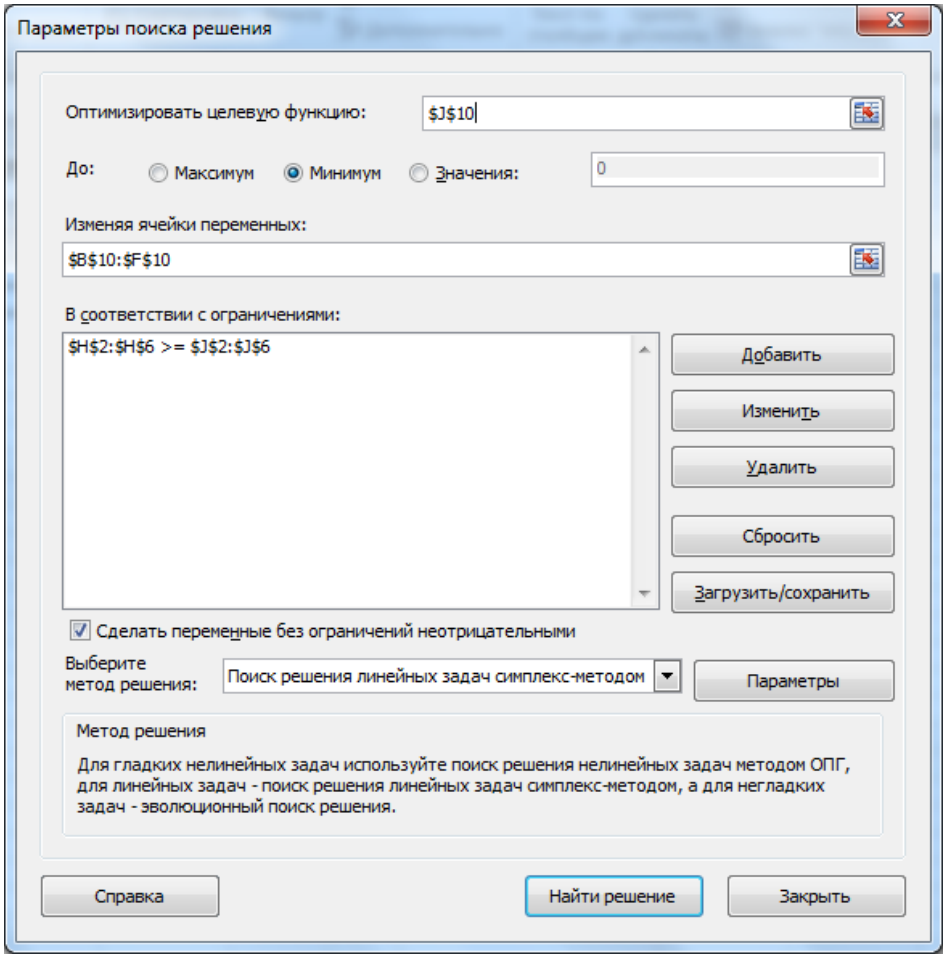


Figure 2. The Solver add-in options window

By clicking on the “Parameters” button you can change the search parameters: the solution search method, the calculation time, and the accuracy of the results.

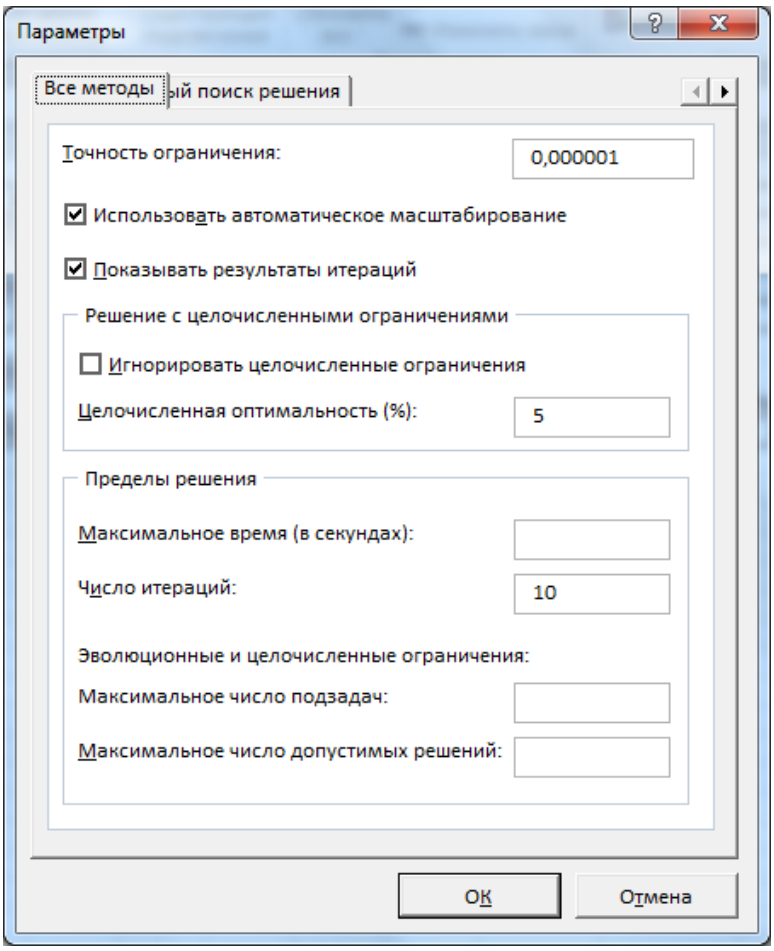


Figure 3. Dialog box for setting the solution search parameters

In general, using the default settings will be sufficient. This window also allows you to save the search model or load a previously saved model.

When the solution search is successfully completed, the calculation results are entered into the original table, and in the Solution Results window the user has the opportunity to select the following options:

- save the found solution in the original table;
- restore original values;
- save the results as a script;
- generate a report on the results of the operation.

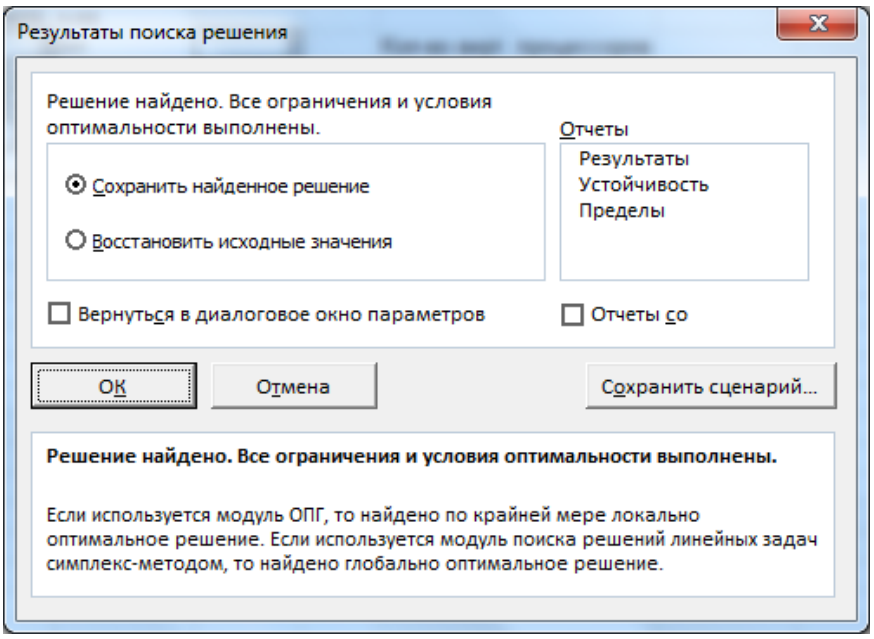


Figure 4. Solution Search Results dialog

The search results report is generated on a separate worksheet and contains information about the original and final values of the target and influence cells and the imposed constraints.

2. Calculating the resource provision plan

Using the software described above, we calculate the lowest-cost VM combination that satisfies the system requirements of an application running in a cloud-based data center. The system under consideration utilizes five types of VMs (Table 1), which are used to support a finite set of application instances requiring identical resource volumes.

Table 1. Virtual machine types

No.	Price per hour, $	Name	vCPU (number of processors)	ECU (performance virtual processor)	RAM, GB	Device storage, GB	Network Performance
1	0.209	r3.xlarge	4	13	30.5	80	Average(3)
2	0.190	m3.xlarge	4	13	15	80	High(4)
3	0.111	m2.xlarge	2	6.5	17.1	420	Average(3)
4	0.146	c3.xlarge	4	14	7.5	80	Average(3)
5	0.767	g2.2xlarge	8	26	15	100	High(4)

Here, a vCPU (virtual CPU) is a virtual processor whose performance is measured in ECUs (EC2 Compute Units). According to the information, one ECU corresponds to a 1–1.2 GHz AMD Opteron or Intel Xeon processor from 2007. Thus, an r3.xlarge VM instance contains 30.5 GB of RAM, four processors with 13 ECUs each, and an 80 GB storage device, while its base price is $0.209 per hour. These VM types were selected from a set of VM instances developed by Amazon EC2, a leader in the virtualization market. Let us denote the types of VMs r3.xlarge, m3.xlarge, m2.xlarge, c3.xlarge, g2.2xlarge as F_1, F_2, F_3, F_4, F_5 respectively, and the technical characteristics of VMs as N_1, N_2, N_3, N_4, N_5, where N_1 is the number of virtual processors: {4; 4; 2; 4; 8}, N_2 is the measure of processor performance: {13; 13; 6.5; 14; 26}, N_3 is the amount of RAM in GB: {30.5; 15; 17.1; 7.5; 15}, N_4 is the data storage device in GB: {80; 80; 420; 80; 100}, N 5 is a measure of network performance, where very low performance is 1, low is 2, average is 3, and high is 4: {3;4;3;3;4}. Based on (1) and the introduced notations, we construct a matrix of virtual resources of the data center:

$$
\begin{array}{c|ccccc}
 & F_1 & F_2 & F_3 & F_4 & F_5 \\
\hline
N_1 & 4 & 4 & 2 & 4 & 8 \\
N_2 & 13 & 13 & 6.5 & 14 & 26 \\
N_3 & 30.5 & 15 & 17.1 & 7.5 & 15 \\
N_4 & 80 & 80 & 420 & 80 & 100 \\
N_5 & 3 & 4 & 3 & 3 & 4
\end{array}
$$

Let's assume that the following minimum technical specifications are required to run a single instance of the application: 3 virtual processors with a performance of 8 ECUs, 4.096 GB of RAM, a 100 GB storage device, and average network performance. Then the constraint vector has the form $b^T = (3; 8; 4.096; 100; 3)$ and we get:

$$4x_1 + 4x_2 + 2x_3 + 4x_4 + 8x_5 \geq 3$$

$$13x_1 + 13x_2 + 6.5x_3 + 14x_4 + 26x_5 \geq 8,$$

$$30.5x_1 + 15x_2 + 17.1x_3 + 7.5x_4 + 15x_5 \geq 4.096,$$

$$80x_1 + 80x_2 + 420x_3 + 80x_4 + 100x_5 \geq 100,$$

$$3x_1 + 4x_2 + 3x_3 + 3x_4 + 4x_5 \geq 3.$$

It is clear from the problem that all variables $x_1, x_2, \ldots, x_n$ are non-negative. Based on this, the following inequalities are added to the constraints:

$$x_1 \geq 0,$$

$$x_2 \geq 0,$$

$$\ldots,$$

$$x_5 \geq 0.$$

From the table, we can derive the cost vector of the VM type $F_1, F_2, \ldots, F_5$, which is written as follows:

$$c^T = (0.209; 0.190; 0.111; 0.146; 0.767).$$

Therefore, the cost of the entire capacity allocation $x^T = (x_1, x_2, \ldots, x_5)$ can be written as an objective function:

$$0.209x_1 + 0.190x_2 + 0.111x_3 + 0.146x_4 + 0.767x_5 \rightarrow min$$

The problem of finding the cheapest allocation of virtual resources can be expressed in the following matrix-vector form:

$$0.209x_1 + 0.190x_2 + 0.111x_3 + 0.146x_4$$

$$+0.767\, x_5 \rightarrow min$$

$$4x_1 + 4x_2 + 2x_3 + 4x_4 + 8x_5 \geq 3$$

$$13x_1 + 13x_2 + 6.5x_3 + 14x_4 + 26x_5 \geq 8,$$

$$30.5x_1 + 15x_2 + 17.1x_3 + 7.5x_4 + 15x_5 \geq 4.096,$$

$$80x_1 + 80x_2 + 420x_3 + 80x_4 + 100x_5 \geq 100,$$

$$3x_1 + 4x_2 + 3x_3 + 3x_4 + 4x_5 \geq 3$$

$$x_1 \geq 0,\ x_2 \geq 0,\ \ldots,\ x_5 \geq 0.$$

Application performance options implemented by virtual machines

Option number	Characteristics of the implemented Applications				
	Number of virtual processors (N1)	Virtual processor performance (N2)	RAM capacity (N3), GB	Disk capacity (N4), GB	Network performance (N5)
1	2	6.5	3.76	100	3
2	3	13	3,25	75	4
3	4	6,5	4,73	70	3
4	5	14	4,96	60	3

5	2	13	2,35	100	4
6	3	26	4,57	35	4
7	4	6,4	3,96	80	3
8	5	26	2.73	85	4
9	3	14	3.84	90	3
10	4	13	5.23	100	4

Calculations of the system of equations are performed using the "Solver" add-in in a Microsoft Excel table.

To perform calculations, the following steps must be completed:

1. Activate the MS Add-on Package Excel "Solver".

1.1. Click the Options button in the File menu.

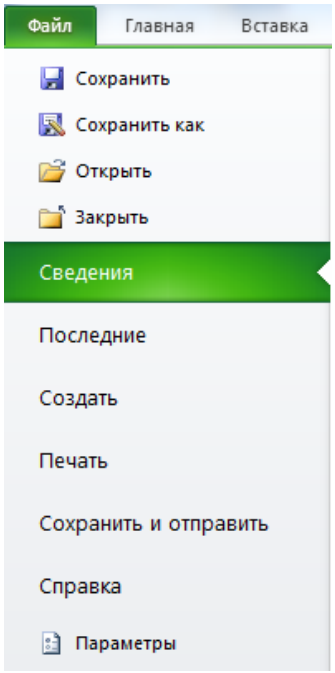


Figure 5. Location of the "Options" button in the MS package Excel

1.2. Excel Options " window that opens, select the "Add-ons" tab:

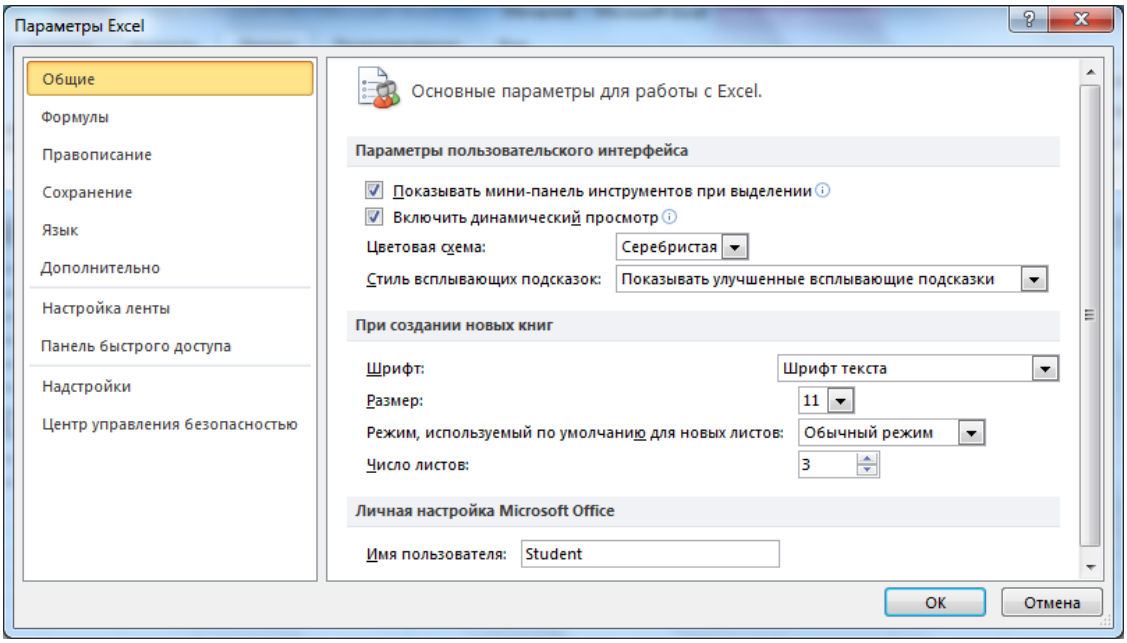


Figure 6. The Excel Options window

1.3. Select "Solution Search" from the list of available add-ons and click the "Go" button.

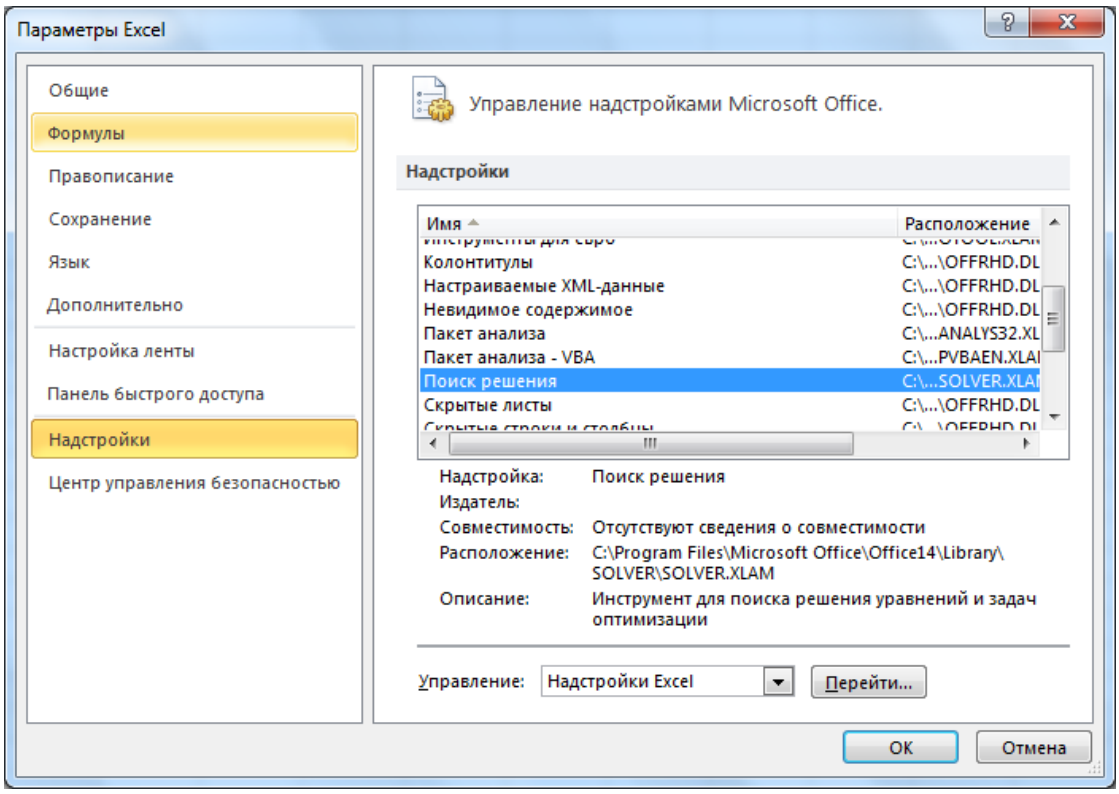


Figure 7. List of available add-ons in MS Excel

1.4. In the window that opens, answer the question “Search for solutions” and click the “OK” button.

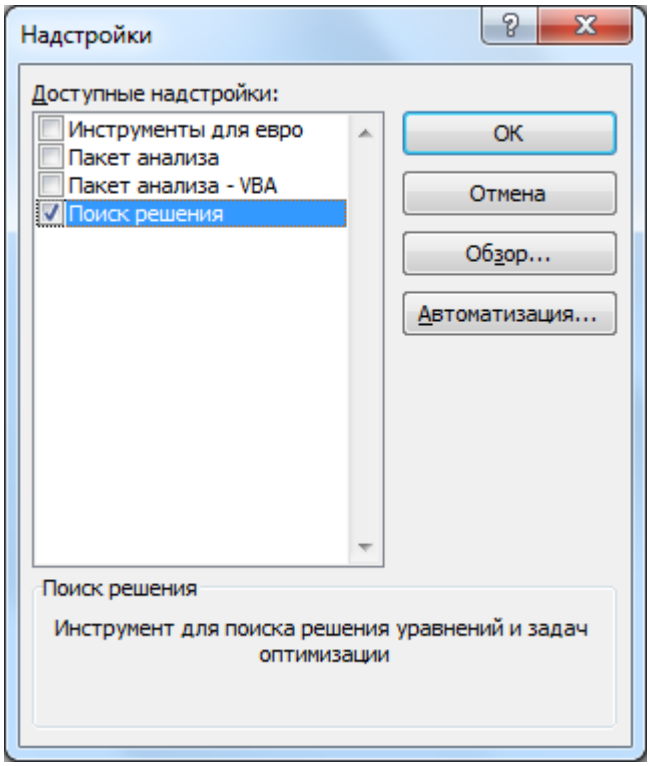


Figure 8. List of connected add-ons

2. Create a table of the following type :

	A	B	C	D	E	F	G	H	I	J	K	L
1		F1	F2	F3	F4	F5		Треб. техн.	ч-ки			
2	N1	4	4	2	4	8		3	>=	3		Кол-во вирт. процессоров
3	N2	13	13	6,5	14	26		1,03E+01	>=	10,25		Произв. процессоров
4	N3	30,5	15	17,1	7,5	15		1,23E+01	>=	12,3		Объем ОЗУ
5	N4	80	80	420	80	100		250	>=	250		Объем НЖДМ
6	N5	3	4	3	3	4		3	>=	3		Произв. сети
7												
8	Ст-ть	0,209	0,19	0,111	0,146	0,767						
9										Итог. стоим.		
10	X	1,39E-16	0	0,5	0,5	0				0,1285		
11												
12												
13												

Figure 9. Structure of the calculation table

3. the source data values into the calculation table. Characteristics F1..F5 of virtual machines N1..N5 are entered into cells in the range B2 : F6 . The performance characteristics required by the applications are entered into the range J2 : J6 . The hourly costs of virtual machines N1..N5 are entered into the range B8 : F8 .

4. Enter the formulas in the calculation table according to table 2:

Table 2. Values of the cell calculation table

Cell address	Formula in cell
H 2	=$B2*$B$10+$C2*$C$10+$D2*$D$10+$E2*$E$10+$F2*$F$10
H 3	=$B3*$B$10+$C3*$C$10+$D3*$D$10+$E3*$E$10+$F3*$F$10
H 4	=$B4*$B$10+$C4*$C$10+$D4*$D$10+$E4*$E$10+$F4*$F$10
H 5	=$B5*$B$10+$C5*$C$10+$D5*$D$10+$E5*$E$10+$F5*$F$10
H 6	=$B6*$B$10+$C6*$C$10+$D6*$D$10+$E6*$E$10+$F6*$F$10
J 10	=B10*B8 + C10*C8 + D10*D8 + E10*E8+F10*F8

5. The Solver button from the Analysis group on the Data tab is clicked.

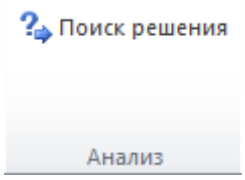


Figure 10. Location of the "Solver" button in MS Excel

6. In the "Solver search parameters" window that appears, enter the solution search parameters:

— what value the obtained result will tend to (minimum, maximum or just value);

— which variable cells are changed;

— restrictions ;

— solution method (in this work, “Searching for solutions to linear problems using the simplex method” is used).

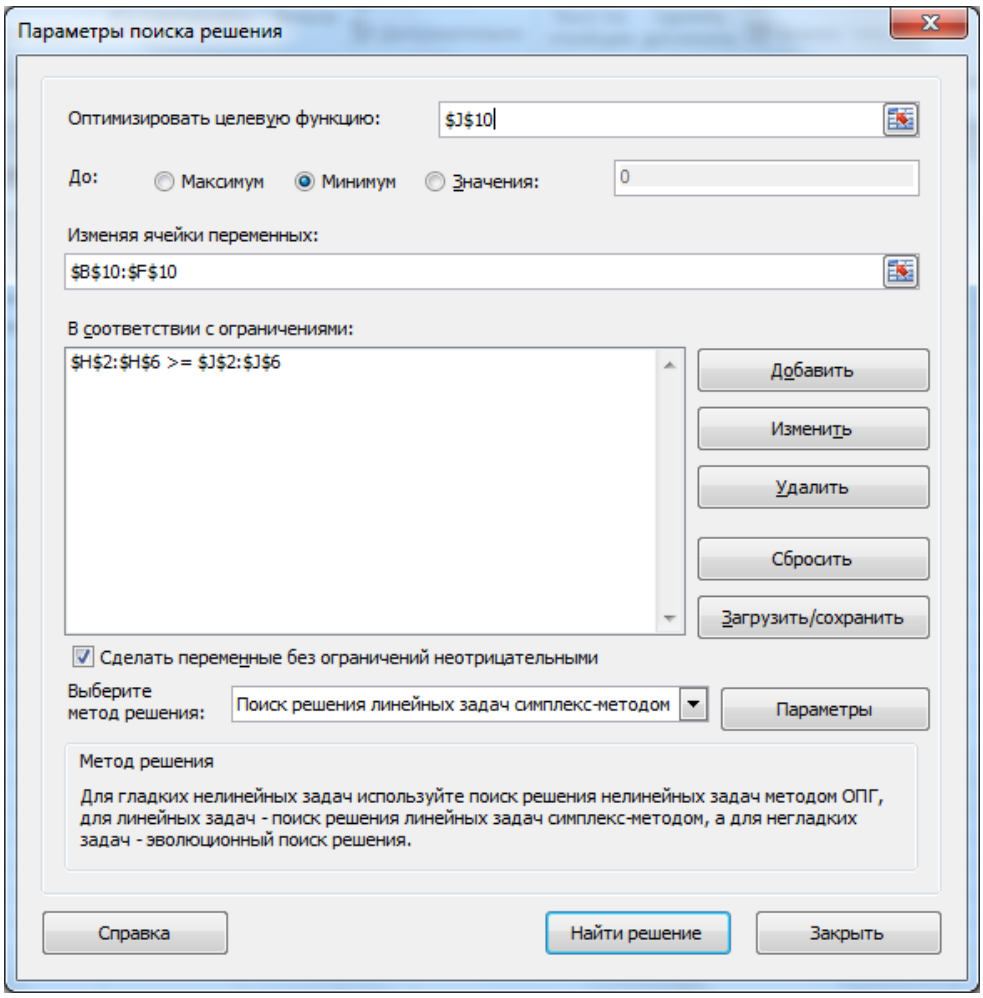


Figure 10. Solution search parameters.

You can also enter a more precise search for a solution by clicking “Options” (Figure 12).

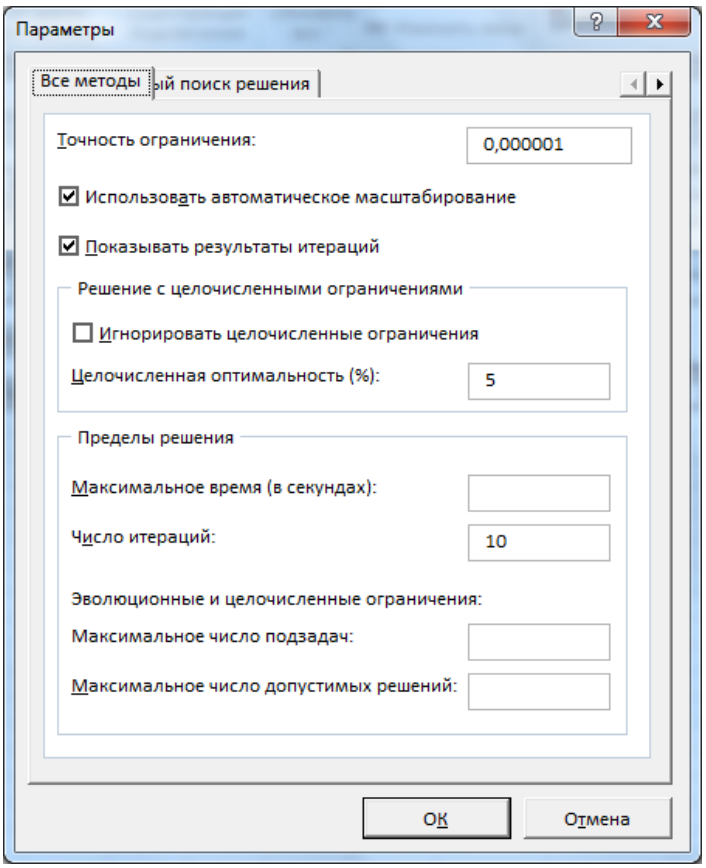


Figure 12. Additional parameters for searching a solution

Here it is stated:

1) Limiting accuracy (in work 0.000001) ;

1) Automatic scaling (enabled in the work, because the results could vary significantly);

2) Integer optimality shows that in work 5% of the integer number the constraint has the right to be;

3) Number of iterations 10 .

7. Run the solution by clicking the "Solve" button in the "Solver Options" window. When the "Show Preview Solution" window appears, click "Continue."

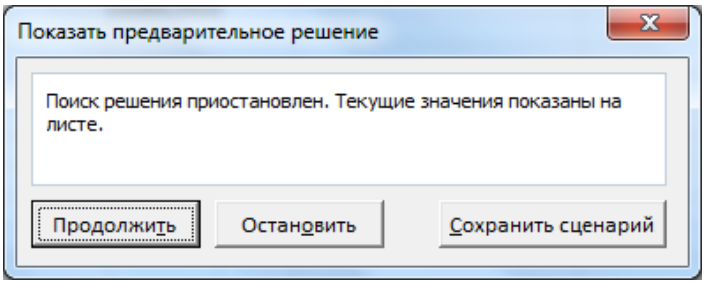


Figure 13. Preliminary results window

8. When the "Solution Results" window appears, save the result. To do this, select "Save Solution Results," click "Results," and confirm saving by clicking "OK." This will create an additional tab with the results.

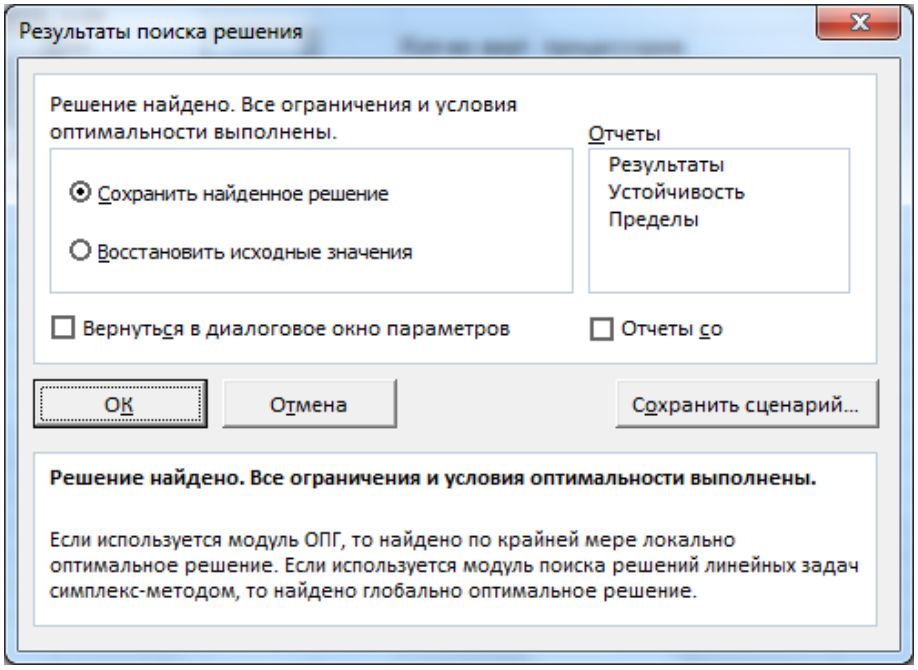


Figure 14. Solution search results window

The problem posed can be classified as a linear programming problem , and its solution was found using the simplex method. Nine iterations were performed to obtain the optimal plan using the basic simplex method. The time to calculate the optimal plan using Microsoft Excel on a personal computer with the following

system parameters: Intel CORE i5, 2.5 GHz processor, 4 GB RAM was 6.241 seconds (Figure 15).

$$x_1 = 0,\ x_2 = 0,\ x_3 = 0.5,\ x_4 = 0.5,\ x_5 = 0,$$
$$F(x) = 0.5 \cdot 0.111 + 0.5 \cdot 0.146 = 0.129. \qquad (12)$$

The optimal plan for providing virtual resources can be written as follows:

Microsoft Excel 16.0 Отчет о результатах
Лист: [Таблица Типы ВМ.xlsx]Лист1
Отчет создан: 30.04.2020 19:35:31
Результат: Решение найдено. Все ограничения и условия оптимальности выполнены.
Модуль поиска решения
Модуль: Поиск решения лин. задач симплекс-методом
Время решения: 6,241 секунд.
Число итераций: 9 Число подзадач: 0
Параметры поиска решения
Максимальное время Без пределов, Число итераций 9, Precision 0,000001, Использовать автоматическое масштабирование, Показывать результаты итераций
Максимальное число подзадач Без пределов, Максимальное число целочисленных решений Без пределов, Целочисленное отклонение 5%, Считать неотрицательными

Ячейка целевой функции (Минимум)

Ячейка	Имя	Исходное значение	Окончательное значение
$J$10	ЦФ=	0,1285	0,1285

Ячейки переменных

Ячейка	Имя	Исходное значение	Окончательное значение	Целочисленное
$B$10	X F1	0	0	Продолжить
$C$10	X F2	0	0	Продолжить
$D$10	X F3	0,5	0,5	Продолжить
$E$10	X F4	0,5	0,5	Продолжить
$F$10	X F5	0	0	Продолжить

Ограничения

Ячейка	Имя	Значение ячейки	Формула	Состояние	Допуск
$H$2	N1 Треб. техн.х-ки	3	$H$2<=$J$2	Привязка	0
$H$3	N2 Треб. техн.х-ки	8	$H$3<=$J$3	Без привязки	2,25
$H$4	N3 Треб. техн.х-ки	4,096	$H$4<=$J$4	Без привязки	8,204
$H$5	N4 Треб. техн.х-ки	100	$H$5<=$J$5	Без привязки	150
$H$6	N5 Треб. техн.х-ки	3	$H$6<=$J$6	Привязка	0

Figure 15. Result of cost function optimization

The resulting solution may indicate that to provide the cheapest provisioning of the resources required to run one application instance, 0.5 VM instances of type 3 and 0.5 VM instances of type 4 will be required, and the minimum cost of such provisioning will be $0.129 per hour.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		F1	F2	F3	F4	F5		Треб. техн.х-						
2	N1	4	4	2	4	8		3		3		Кол-во. Вирт. Процесоров		
3	N2	13	13	6,5	14	26		8		10,25		Произв. Процессора		
4	N3	30,5	15	17,1	7,5	15		4,096		12,3		Обьем ОЗУ		
5	N4	80	80	420	80	60		100		250		Объем НЖМД		
6	N5	3	4	3	3	4		3		3		Произв. Сети		
7														
8	Ст-ть	0,209	0,19	0,111	0,146	0,767								
9														
10	X	0	0	0,5	0,5	0			ЦФ=	0,1285				
11														

Figure 16. The value of the objective function after searching for a solution to the problem using the simplex method

Along with the obtained results, it is known that the main existing virtualization tools (for example, Windows Azure) use the principle of providing each application instance with a separate VM. Only after analyzing the performance of running application instances does the platform allocate additional VM instances or reduce unused ones. This approach is more expensive in terms of cloud service utilization.

From this, we can conclude that the practical effect of the resulting solution lies in the cost-effectiveness of using cloud services due to the fact that the number of virtual machines used is reduced.

Thus, with the "classic" approach, 1,000 g2.2xlarge virtual machine instances are used to run 1,000 instances of a virtual application with given characteristics, at a cost of $0.767 per hour (table), resulting in a service cost of $767 per hour. This is because running 1,000 instances of the application requires 100,000 GB of data storage, while one g2.2xlarge VM can only provide 100 GB. Furthermore, using the proposed algorithm, taking into account the result, the service cost will be $129 per hour, which reduces the cost of running 1,000 instances of the application by 83%.

MINISTRY OF SCIENCE AND HIGHER EDUCATION
RUSSIAN FEDERATION

FEDERAL STATE AUTONOMOUS EDUCATIONAL INSTITUTION OF HIGHER EDUCATION
NORTH CAUCASIAN FEDERAL UNIVERSITY

GUIDELINES
on organizing students' independent work
in the discipline Mathematical Modeling

Training direction 11.03.02 Infocommunication technologies and communication systems
Profile: Intelligent Data Processing in Infocommunication Systems and Networks

Stavropol, 2026

The guidelines for organizing students' independent work are compiled in accordance with the requirements of the "Mathematical Modeling" discipline program in the Infocommunication Technologies and Communication Systems program.
This teaching aid is devoted to planning students' academic work performed outside of class (classroom) time on assignment and with the methodological guidance of the teacher, but without his direct participation (with partial direct participation of the teacher).

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1. Independent work as the most important form of the educational process

Independent work -is planned educational, educational and research, scientific research work of students, carried out outside of class (classroom) time on assignment and with the methodological guidance of the teacher, but without his direct participation (with partial direct participation of the teacher, leaving the leading role to the students' work).

Independent student work at a university is an important form of academic and research activity. Independent student work plays a significant role in the rating system of learning. Studying at a university involves two parts, almost equal in scope and mutual influence: the learning process and self-study. Therefore, independent student work should be an effective and purposeful part of student work.

The concept for modernizing Russian education defines the main objectives of vocational education as "the preparation of a qualified worker of the appropriate level and profile, competitive in the labor market, competent, responsible, fluent in their profession and oriented in related fields of activity, capable of effective work in their specialty at the level of world standards, ready for continuous professional growth, social and professional mobility."

The solution to these problems is impossible without increasing the role of students' independent work on educational material, strengthening the responsibility of teachers for developing independent work skills, stimulating students' professional growth, and fostering creativity and initiative.

Society places a wide range of demands on modern professionals, among which a significant factor is the ability of graduates to independently acquire knowledge from various sources, systematize acquired information, and assess a specific financial situation. This ability is developed throughout the entire educational period through students' participation in practical classes, completing assignments and tests, and writing coursework and final theses. Students' independent work plays a crucial role throughout the entire educational process.

The first step requires familiarization with the required minimum content of the core educational program for the discipline being studied. Next, you need to review the course syllabus, which covers the content of lecture course topics, the relationship between lecture topics and laboratory and practical classes, as well as the topics and types of independent work. Specific reporting forms are provided for each type of independent work.

To successfully master the course, you must independently and thoroughly study the presented topics using the recommended sources of information.

2. Goals and main objectives of the SRS

The primary goal of organizing and implementing independent work should align with the goal of student education—the preparation of a bachelor's degree holder with a higher education degree. When organizing independent work, developing the ability to work independently to acquire knowledge, skills, and the ability to organize educational and research activities is an important and necessary condition.

The goal of students' independent work is to acquire fundamental knowledge, professional skills, and relevant professional abilities, as well as experience in creative and research activities. Independent work promotes the development of students' independence, responsibility, self-discipline, and a creative approach to solving academic and professional problems.

The objectives of the SRS are:

- systematization and consolidation of the acquired theoretical knowledge and practical skills of students;
- deepening and expanding theoretical knowledge;
- development of skills in using regulatory, legal, reference documentation and specialized literature;
- development of students' cognitive abilities and activity: creative initiative, independence, responsibility and organization;
- development of independent thinking, abilities for self-development, self-improvement and self-realization;
- development of research skills;
- use of material collected and obtained during independent study at seminars, in practical and laboratory classes, when writing coursework and final qualifying papers, for effective preparation for final tests and exams.

3. Types of independent work

In the educational process at a higher professional educational institution, two types of independent work are distinguished : in-class, under the guidance of a teacher, and out-of-class. The close interrelationship between these types of work allows for differentiation and the effectiveness of their results and depends on the organization, content, and logic of the educational process (interdisciplinary connections, advanced knowledge, etc.) :

Independent classroom work on the subject is carried out during classes under the direct supervision of the teacher and according to his/her instructions.

Extracurricular independent work is performed by a student on the teacher's instructions, but without his or her direct participation.

The main types of independent work of students without the participation of a teacher in this discipline are:

- formation and assimilation of the content of lecture notes based on the educational literature recommended by the lecturer, including information educational resources (electronic textbooks, electronic libraries, etc.);
- preparation for laboratory work, its design.

The main types of independent work of students with the participation of teachers are:

- ongoing consultations;
- acceptance and defense of laboratory work (during laboratory work).

4. Organization of the SRS

The methodology for organizing students' independent work depends on the structure, nature, and characteristics of the discipline, the number of hours for its study, the type of assignments for students' independent work, the individual qualities of students, and the conditions of educational activities.

The process of organizing students' independent work includes the following stages:

- preparatory (defining goals, drawing up a program, preparing methodological support, preparing equipment);
- basic (implementation of the program, use of techniques for searching for information, assimilation, processing, application, transfer of knowledge, recording of results, self-organization of the work process);
- final (assessment of significance and analysis of results, their systematization, assessment of the effectiveness of the program and work methods, conclusions on areas of labor optimization).

Students' activities to form and develop skills for independent study.

In the process of independent work, the student acquires the skills of self-organization, self-control, self-management, self-reflection and becomes an active, independent subject of educational activity.

Doing independent work under the supervision of a teacher

The student must:

–master the minimum content assigned to students for independent work and proposed by the teacher in accordance with the educational standards of higher education;

–plan independent work in accordance with the independent work schedule proposed by the teacher;

– The student must carry out independent work in the organizational forms provided for by the curriculum and the teacher's work program;

– carry out independent work and report on its results in accordance with the schedule for presenting results, types and deadlines for reporting on students' independent work.

a student can:

in addition to that proposed by the teacher (subject to justification and agreement with him) and the minimum required content determined by the program for a given discipline:

– independently determine the level (depth) of elaboration of the content of the material;

– suggest topics and questions for independent study;

– within the general schedule for completing independent work, propose a reasonable individual schedule for completing and reporting on the results of independent work;

– propose your own options for organizational forms of independent work;

– use for independent work methodological aids, teaching aids, and developments in addition to the list proposed by the teacher;

– use not only control, but also self-control of the results of independent work in accordance with the methods of self-control proposed by the teacher or chosen independently.

Students' independent work should have a significant impact on the development of their future bachelor's degree students. It is planned by the student themselves. Each student determines their own work schedule and the amount of effort expended on mastering the academic content in each subject. They complete their extracurricular work according to their individual plan, depending on their preparation, time, and other circumstances.

5. General recommendations for organizing independent work

The primary form of student independent work is studying lecture notes, supplementing them, referring to recommended literature, and actively participating in laboratory classes. However, to ensure successful learning and its intensification, the following subjective factors must be considered:

1. Knowledge of the school curriculum and a solid system of gaps necessary for mastering core university courses. This is especially important for mathematical subjects. It is important to distinguish between gaps in knowledge that hinder the assimilation of new material and limited abilities. By investing effort in overcoming these gaps, the student will ensure adequate academic performance and gain confidence in their abilities.

2. Availability of skills and abilities for mental work:

a) the ability to take notes during lectures and when working with a book;

b) mastery of logical operations: comparison, analysis, synthesis, generalization, definition of concepts, rules of systematization and classification.

3. The specificity of cognitive mental processes: attention, memory, speech, observation, intellect, and thinking. Poor development of any of these can become a serious obstacle to learning.

4. Good performance, which is ensured by normal physical condition. After all, serious study is a complex, multifaceted, and varied undertaking. Learning outcomes are assessed not by the quantity of information imparted, but by the quality of its assimilation, the ability to use it, and the development of one's capacity for further independent learning.

5. Match your chosen activity or profession to your individual abilities. It's essential to develop the ability to self-regulate your emotional state and eliminate circumstances that disrupt your professional spirit and interfere with your intended work.

6. Mastering an optimal work style that ensures success in your work. Alternating work and breaks, rest periods, individually determined sleep duration, preference for evening or morning classes, stress tolerance during exams, and specific preparation techniques.

7. The level of demands on oneself, determined by the established self-esteem.

An adequate assessment of knowledge, strengths, and weaknesses is an important component of human self-organization; without it, successful work on managing one's behavior and activities is impossible.

One of the main features of higher education is that constant external control is replaced by self-control; the active role in learning belongs not so much to the teacher as to the student.

Knowing the basic methods of scientific organization of mental work, one can achieve the best results with the least expenditure of time, resources and labor effort.

The effectiveness of assimilation of incoming information depends on a person’s performance at any given moment of his activity.

Work capacity is a person's ability to work at a high level of intensity for a certain period of time. A distinction is made between internal and external factors of work capacity.

Internal factors of performance include intellectual abilities, willpower, and health status.

To external:

- organization of the workplace, work and rest schedule;
- level of work organization - ability to obtain information and use it;

- the amount of mental workload.

The outstanding Russian physiologist N.E. Vvedensky identified the following conditions for the productivity of mental activity:

- you need to enter into any work gradually;
- the regularity and rhythm of work. Different people have more or less different work tempos;
- habitual sequence and systematicity of activity;
- correct alternation of work and rest.

Rest doesn't necessarily require complete inactivity; it can be achieved by simply changing tasks. Work capacity fluctuates throughout the day. The most productive *time is morning (8:00 a.m. to 2:00 p.m.),* with peak productivity occurring between 10:00 a.m. and 1:00 p.m., followed by *afternoon* (4:00 p.m. to 7:00 p.m.) and *evening* (8:00 p.m. to midnight). It's best to study very difficult material at the beginning of each work period (preferably morning) after a good rest. Breaks of 10-15 minutes are needed after 1-1.5 hours of work, and after 3-4 hours of work, rest should be longer – about an hour.

An integral part of the scientific organization of mental work is the mastery of the technique of mental work.

The time available for students to complete their curriculum consists of two components: one is scheduled classroom work at the university, and the other is independent work outside of class. Assignments and materials for independent work are provided during scheduled classes. During these classes, the instructor monitors independent work and assists students in organizing their work properly.

Independent study requires intense mental effort, which must not only be properly organized but also stimulated. It's crucial to be able to maintain sustained attention to the material being studied. Developing attention requires considerable willpower. Therefore, if a student notices they are frequently distracted during independent study, they should force themselves to focus. This process should be repeated regularly, as it trains their attention. Sustained attention develops when a person approaches the subject with interest.

It's important to organize your activities properly: 50 minutes of work, 5-10 minutes of breaks; after 3 hours of work, take a 20-25 minute break. Otherwise, increasing fatigue will lead to a loss of focus. Regular physical exercise is a very important factor in improving mental performance. Organizing active recreation involves alternating mental and physical activity, which fully restores a person's performance.

6. Independent work of a student is a necessary part of becoming a researcher

The progress of science and technology, information technology leads to a significant increase in scientific information, which places higher demands not only on the moral and ethical qualities of a person, but also, in particular, constantly increasing demands in the field of education - updating, modernization of general and professional knowledge, skills of a specialist.

All education should be a dynamic process, inherent to the individual and continuing throughout their life. Mastering scientific thought and the language of science is a necessary component in the self-organization of a future research specialist. This implies not so much the accumulation of knowledge as the mastery of scientifically sound methods for acquiring it. This, generally speaking, is the primary task of a university.

The specific nature of the university educational process, in which - independent student work is increasingly given prominence, is that it seems to be the final and most appropriate link in achieving this goal. During university studies, a style and skills of learning (cognitive) activity are developed, the rational nature of which will facilitate the constant renewal of knowledge in highly qualified university graduates.

However, this path faces certain challenges, particularly the student's transition from the synthetic learning process in secondary school to the analytical one in higher education. This is due both to the new content of instruction (the expansion of general education and the deepening of professional training) and to new, previously unknown forms of learning (lectures, seminars, laboratory classes, etc.). Students acquire not only the knowledge provided by the curriculum and textbooks but also must become familiar with the methods of acquiring knowledge so as to be able to evaluate what we know, where we know it from, and how we acquired it. All of this is achieved through independent work.

This is because independently acquired knowledge is more immediate, becoming personal property and a motivation for behavior, developing intellectual traits, attention, observation, critical thinking, and judgment. The teacher's role primarily consists of guiding the accumulation of knowledge (for first-year students), and in subsequent years, during senior years, collaboratively identifying problems and supporting students' independent explorations, as well as monitoring their activities. It should be noted that one should not limit oneself to acquiring the knowledge stipulated by the program of the discipline being studied; one must continually deepen the acquired knowledge, focusing it on a narrow, specific area that corresponds to the student's interests. In-depth study of all subjects covered by the program is possible in practice, and good organization of work allows for time

savings, creating the conditions for a deep, systematic, and engaging study of the topic independently chosen by the student.

Of course, all the advice, examples, and recommendations in this area, whether given by a teacher, certain publications, or other sources, do not guarantee any success without personal action. They do not provide ready-made recipes, but should encourage an analysis of one's own work, its goals, and its organization in accordance with individual characteristics. Taking into account personal capabilities, existing living and working conditions, and skills, based on these recommendations, it is possible to develop an individually substantiated set of methods and techniques, find one's own style, or refine it. After studying specific material, one has time to evaluate its significance, suitability, and potential for its application, ultimately ensuring the success of one's studies and future professional activities.

7. Methodological recommendations for students on certain forms of independent work

The university education system requires students to have significantly greater independence in planning and organizing their activities. This can be quite challenging for a recent high school student: while at school, daily teacher supervision forced students to constantly and systematically prepare for classes, at university, the question of their knowledge level only really arises during exam periods. This situation leads some to the temptation to devote the entire semester to free time ("I'll learn it when I need to!"), and when exam time arrives, the material to be mastered is so overwhelming that no memory can cope with it in the remaining time.

Working with literature.

When working with books, you need to select literature, learn to read it correctly, and keep records. To select literature, the library uses alphabetical and systematic catalogs.

It is important to remember that rational skills in working with a book always mean great savings of time and effort.

The instructor teaching the course recommends the appropriate selection of textbooks. Required literature may also be listed in the course's teaching materials.

When studying the material in a textbook, you should move on to the next question only after correctly understanding the previous one, describing on paper all the calculations and computations (including those that are omitted from the textbook or given in the lecture for independent derivation).

When studying any discipline, independent individual work plays a large and important role.

Particular attention should be paid to defining the course's key concepts. Students should thoroughly analyze examples that illustrate these definitions and be able to construct similar examples independently. It's important to develop a clear understanding of what you're learning. Taking supporting notes is helpful. When studying the material from the textbook, it's helpful to supplement your lecture notes in the designated margins in your notebook. You should also note any questions you've identified for consultation with the instructor.

It is recommended to highlight the conclusions obtained as a result of the study in the notes so that they are better remembered when rereading the notes.

Experience shows that many students find it helpful to create a reference sheet containing the most important and frequently used formulas and concepts. Such a sheet helps students remember formulas and key points of the lecture, and can also serve as a constant reference for them.

There are two types of reading: primary and secondary. *Primary* reading is attentive, unhurried reading, allowing you to pause at difficult passages. Afterward, there shouldn't be a single unclear point. The content may not always be clear after the primary reading.

The goal *of secondary* reading is to fully grasp the meaning of the whole (this reading may not be the second, but the third or fourth).

Rules for independent work with literature.

As already noted, independent study of textbooks and books (as well as independent theoretical research into the problems outlined by the instructor in lectures) is a crucial prerequisite for developing a scientific approach to learning. The main tips here can be summarized as follows:

• Make a list of books that you should get acquainted with; “don’t try to remember everything that you won’t need in the near future,” advises G. Selye to the student and young scientist, “just remember where you can find it” (Selye, 1987. P. 325).

• The list itself should be systematized (what is needed for seminars, what is needed for exams, what will be useful for writing term papers and theses, and what interests you outside the framework of official educational activities, that is, what can expand your general culture...).

• Be sure to write out all the output data for each book (when writing term papers and theses, this will save a lot of time).

• Figure out for yourself which books (or which chapters of books) you should read more carefully, and which you should just skim through.

• When compiling a list of literature, you should consult with teachers and academic supervisors (or even with more prepared and erudite fellow students), who will help you better understand what is worth paying more attention to, and what is not worth wasting time on at all...

•Naturally, all books, textbooks and articles read should be taken down, but this does not mean that you have to take down “everything”: you can briefly write down the author’s main ideas and sometimes provide the most striking and illustrative quotes (with page numbers).

• If the book is your own, then it is permissible to make brief notes in the margins of the book, or at the end of the book, on blank pages, simply make your own “subject index”, where you note the thoughts that are most interesting to you and be sure to indicate the pages in the author’s text (this is very good advice, allowing you to save time and quickly find “favorite” places in a wide variety of books).

• If you have not worked much with scientific literature before, you should develop the ability to "perceive" complex texts; the best technique for this is to learn to "read slowly", when you understand every word you read (and if the word is unfamiliar, then you must either look it up with a dictionary or with the help of a teacher), and this can take a considerable amount of time (for some, up to several weeks or even months); experience shows that after this, the student, by some "miracle", literally begins to swallow books and almost see "through the cover" whether the work is worthwhile or not...

• “Either read or skim the material, but don’t try to read quickly... If the text interests me, then reading, thinking, and even fantasizing about it merge into a single process, while forced speed reading not only does not contribute to the quality of reading, but also does not bring the feeling of satisfaction that we get from thinking about what we have read,” advises G. Selye (Selye, 1987. – Pp. 325-326).

• Another effective way to optimize your exposure to scientific literature is to become captivated by a particular idea and then review all books from that perspective. In this case, the student (or young scientist) will seek arguments for or against the idea in question, while simultaneously engaging with the authors of these books about their own ideas and reflections. The only problem is how to find "your" idea.

Reading scientific text is part of cognitive activity. Its goal is to extract the necessary information from the text. The effectiveness of the action largely depends on how consciously the reader approaches the printed word (finding the necessary information, assimilating it in whole or in part, critically analyzing the material, etc.).

There are ***four main attitudes towards reading scientific text*** :

1. information retrieval (the task is to find and highlight the desired information)
2. assimilative (the reader's efforts are aimed at fully comprehending and remembering both the information presented by the author and the entire logic of his reasoning)
3. analytical-critical (the reader strives to critically comprehend the material, having analyzed it, and determined his attitude toward it)
4. creative (creates in the reader a readiness in one form or another - as a starting point for his own reasoning, as an image for action by analogy, etc. - to use the author's judgments, his train of thought, the result of observation, the developed methodology, to supplement them, to subject them to new testing).

types of reading is associated with the presence of various settings for accessing scientific text :

1. bibliographic – viewing catalogue cards, recommended lists, summary lists of journals and articles for the year, etc.;
2. Browsing – used to search for materials containing the required information, usually resorted to immediately after working with bibliographies and catalogues, as a result of such browsing the reader determines which sources will be used in further work;
3. introductory – involves a thorough, fairly detailed reading of selected articles, chapters, and individual pages, the goal being to become familiar with the nature of the information, to find out what issues the author has raised for consideration, and to sort the material;
4. Study - involves a thorough mastery of the material; during such reading, the reader's trust in the author is demonstrated, a willingness to accept the information presented is realized, and the goal of a complete understanding of the material is realized;
5. Analytical-critical and creative reading are two types of reading that are related in that they both contribute to solving research problems. The former involves a focused critical analysis of both the information itself and the author's methods of obtaining and presenting it; the latter involves searching for those judgments and facts about which, or in connection with which, the reader considers it necessary to express their own thoughts.

Of all the types of reading discussed, exploratory reading is the most important for students—it allows them to accumulate knowledge in various fields while working with academic literature. Therefore, this type of reading should be mastered first in the learning process. Furthermore, mastering this type of reading

helps develop key techniques that improve the effectiveness of working with scientific texts.

The main types of systematic recording of what has been read:

1. Annotation is an extremely brief, coherent description of a book (article) viewed or read, its content, sources, nature and purpose;
2. Planning is a brief logical organization of the text, revealing the content and structure of the material being studied;
3. Thesis is a concise reproduction of the author's main assertions without using factual material;
4. Quoting is the verbatim copying of excerpts and extracts from the text that most significantly reflect a particular idea of the author;
5. Note-taking is a brief and sequential presentation of the content of what has been read.

A summary is a complex way of presenting the contents of a book or article in a logical sequence. A summary integrates previous notes and allows for a comprehensive understanding of the book or article's content. Therefore, the ability to create an outline, make notes, take excerpts, and other notes determines the technique of summary writing.

Guidelines for writing notes:

1. Read the text carefully. Look up any unfamiliar words in reference books. When taking notes, be sure to include reference information in the margins.
2. Highlight the main points and make a plan.
3. Briefly formulate the main points of the text, note the author's argumentation.
4. Take notes on the material, strictly following the outline. When taking notes, try to express your thoughts in your own words. Keep your notes clear and concise.
5. Write quotes correctly. When quoting, keep in mind the brevity and significance of the idea.

In the summary, it is advisable to present not only thesis statements but also their evidence. When formatting the summary, strive for the conciseness of each sentence. The author's thoughts should be presented concisely, with care taken to maintain style and expressiveness. The number of additional elements in the summary should be logically justified, and entries should be arranged in a specific sequence consistent with the logical structure of the work. Leave margins for clarification and addition.

Mastering note-taking skills requires dedication and independent work on a daily basis from the student.

Practical classes.

It should be emphasized that only after the lecture material has been mastered from a specific perspective (namely, the one from which it is presented in lectures) will it be reinforced in practical classes, both through discussion and analysis of the lecture material and through completing lab assignments and assigned problems. Under these conditions, the student will not only master the material well but also learn to apply it in practice, and will also receive additional incentive (and this is very important) to actively engage with the lecture.

When completing assignments independently, each step of the solution should be justified based on the theoretical principles of the course. If the student sees several possible solutions to a problem (task), they should be compared and the most efficient one selected. It is helpful to create a brief plan for solving the problem (task) before beginning calculations. Solutions to problems or examples should be presented in detail, with calculations arranged in strict order, separating auxiliary calculations from the main ones. Solutions should be accompanied by comments, diagrams, drawings, and illustrations, if necessary.

It's important to remember that each learning task should be completed to the final logical answer required by the conditions, and, if possible, with a conclusion. The resulting answer should be verified using methods appropriate to the nature of the problem. It's also useful (if possible) to solve the problem in several ways and compare the results. For example, this is how tasks are completed using NetCracker. Professional 4.1, then analytically and the obtained results are compared to substantiate the assignment's outcome. Laboratory work. This type of assignment should be continued until solid skills in solving them are acquired.

Self-test.

After studying a specific topic from notes in the notes and textbook, as well as solving a sufficient number of relevant tasks in laboratory classes and independently, the student is recommended, using a sheet of supporting materials, to reproduce from memory the definitions, derivations of formulas, formulations of the main provisions and proofs.

If necessary, you need to carefully review the material again.

Sometimes, a student's lack of understanding of a particular topic only becomes apparent upon further study. In this case, it's necessary to go back and review the poorly understood material. An important criterion for mastering theoretical material is the ability to solve problems or pass tests on the material covered. However, it's important to remember that a correct solution to a problem can result from applying rote memorized formulas without understanding the essence of the theoretical principles.

Consultations

If, while independently studying theoretical material or completing assignments, a student encounters questions that they cannot resolve independently, they should contact the instructor for clarification or guidance. In their questions, students should clearly explain the difficulty they are experiencing and the nature of the difficulty. Consultation should also be sought if they have any doubts about the correctness of their answers to self-assessment questions.

Systematic preparation for classes throughout the semester will allow you to use the time during the exam session to systematize your knowledge.

Ongoing student assessment is conducted by instructors conducting laboratory classes in the discipline. The assessment includes an interview during the lab defense, with a written report submitted. Students are permitted to participate in the lab work upon presentation of a printed version of the report. The report defense takes place in the form of an interview. A student receives the maximum number of points if the report formatting meets established requirements and the report fully explains the essence of the work. Reasons for lowering a student's grade include:

- poorly executed work on a personal computer,
- the written report is completed in a careless manner and contains errors,
- the student does not give a comprehensive answer to the teacher’s question,
- gets confused or has difficulty demonstrating work on the computer.

The report may be sent back for revision in the following cases:

- careless execution and with errors,
- abridged report content.

The interview assessment criteria are provided in the Assessment Tools Fund for the discipline of algorithmization and programming in a high-level language.

8. Independent work of students in the context of a point-rating system of education

A rating system for learning involves multi-point student assessment. However, this isn't a simple transition from a five-point scale. Rather, it allows for the objective reflection of a broader range of assessments of students' individual abilities and their efforts expended on various types of independent work. There's ample scope for creating a series of differentiated individual assignments, each with its own "value." A properly organized rating system allows for a shift away from a five-point grading system from the very beginning and toward a more formal approach only at the end of the course, when students' earned points are converted into standard grades (excellent, good, satisfactory, and unsatisfactory).

Furthermore, the rating system includes additional incentive points for originality and innovative approaches to completing independent work assignments or solving scientific problems. Students have the opportunity to improve their academic standing by participating in extracurricular activities (participating in competitions and conferences; completing individual creative assignments and papers; participating in a science club, etc.). However, students who fail to submit assignments on time may receive negative marks. However, individual students are encouraged to complete the program more quickly. For example, if a student is ready to take a test or write an independent assignment ahead of the class, they may receive additional marks.

A rating system –regularly monitors the quality of knowledge and skills acquired during the educational process and the completion of the planned volume of independent work. A multi-point grading system allows, on the one hand, to reflect students' individual characteristics in a point range, and on the other, –to objectively evaluate the students' efforts expended on individual tasks. Thus, each type of learning activity acquires its own "value." It follows that the "value" of a student's flawless performance is a quantitative measure of their learning, based on the totality of the material they studied that was necessary for successfully completing the assignment.

The maximum possible score for the entire ongoing assessment is set at 55. A current assessment is considered passed if the student receives at least 60% of the maximum score established for that assessment. The rating score assigned to a student for a current assessment completed within the deadlines set in the assessment schedule is determined as follows:

Level of control implementation tasks	Rating score (as a percentage of the maximum score for the test task)
Great	100
Good	80
Satisfactory	60
Unsatisfactory	0

The final grade for a course studied in one semester is determined by the total points earned for work during the semester. The minimum score required for passing is 33 points.

When using the rating system:

- the main emphasis is placed on organizing active types of educational activities; students' activity goes towards creative understanding of the proposed tasks;

- in the relationship between the teacher and students there is cooperation and co-creation, there is a psychological and practical readiness of the teacher to the fact of the individual uniqueness of the “I-concept” of each student;
- a variety of stimulating, emotionally regulating, guiding and organizing techniques of intervention (if necessary) by the teacher in the independent work of students is assumed;
- The teacher acts as a manager and director of learning, ready to offer students the minimum necessary set of learning tools, and not just convey educational information; the student acts as a subject of activity alongside the teacher, and the development of his or her individuality is one of the main educational goals;
- educational information is used as a means of organizing educational activities, and not as a goal of learning.

The rating system of education ensures the greatest informational, procedural and creative productivity of independent cognitive activity of students, provided that it is implemented through the technologies of personally-oriented learning (problem-based, dialogic, discussion, heuristic, game and other educational technologies).

Most students respond positively to this system for tracking their progress, noting that the rating system facilitates an even distribution of their efforts throughout the semester, improves their retention of course material, and ensures systematic work without the stress of rushing through exams. The large number of diverse assignments offered for independent study and the various grading scales allow students to monitor their progress and, if desired, always have the opportunity to improve their rating (by completing additional types of independent work). Organizing the learning process within the rating system, using a variety of independent work options, results in higher student learning outcomes compared to traditional university education.

Using a rating system allows for more consistent student work throughout the semester and also stimulates students' cognitive activity by stimulating their creativity. Tests are also very effective during the learning process, especially when students are working independently. In this case, students test their own knowledge. If they fail to answer a test question immediately, they receive a hint explaining the logic behind it and can then attempt it a second time.

It is also worth noting that automated teaching and teaching-control systems are increasingly penetrating the educational process, allowing students to independently study a particular subject and simultaneously monitor the level of assimilation of the material.

9. Educational, methodological and informational support of the discipline

For this subject, the teacher recommends the following literature:

The following are considered as the main literature:

1. Afonin V.V. Modeling of systems: a tutorial / Afonin V.V. -M .: Internet University of Information Technologies (INTUIT), 2016. - 269 p. - The book is in the basic version of the IPRbooks electronic library system. - ISBN 978-5-9963-0352-6.

As additional literature:

1. Sovetov B.Ya. Modeling of systems: textbook for universities / B. Ya. Sovetov, S. A. Yakovlev; SPbGETU. - 7th ed. - M.: Yurayt, 2013. - 343 p. : ill., table, diagrams. - Grif: Rec. MO. - Bibliography: p. 340-341. - ISBN 978-5-9916-2698-9.

As a teaching and methodological support for independent work:

1. Chernyaeva S.N. Simulation Modeling of Systems. Electronic resource: textbook / V.V. Denisenko / S.N. Chernyaeva; ed. L.A. Korobova. - Simulation Modeling of Systems, 2020-04-27. - Voronezh: Voronezh State University of Engineering Technologies, 2016. - 96 p. - The book is in the basic version of the IPRbooks electronic library system. - ISBN 978-5-00032-180-5

The following Internet resources are offered:

1. http://biblioclub.ru .
2. http://catalog.ncfu.ru/catalog/ncfu .
3. http://www.iprbookshop.ru .

To independently master the theoretical and practical material, you will need the following software:

1. PTC Mathcad Prime. Perpetual license. Agreement No. 29-ea/14 dated July 8, 2014.

Microsoft Basic Software Package Office (Word , Excel , PowerPoint). Microsoft Office Standard 2013: Agreement No. 01-ea/13 dated February 25, 2013, Microsoft Licensing Office https :// support . microsoft . com / ru - ru / lifecycle / search /16674 Life cycle start date 01/09/2013;

3. Office 2013 Service Pack 1 Lifecycle Start Date: February 25, 2014; Mainstream Support End Date: April 10, 2018; Extended Support End Date: April 11, 2023.

4. Operating system: Microsoft Windows 8: 2013-02(3000). Perpetual license. Agreement No. 01-ea/13 dated February 25, 2013. Free support ends in 2023-01.