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Guidelines
on writing Master's Theses

for the students of the specialty 113 "Applied Mathematics"

Graduate departments:
Department of Applied Mathematics
Department of Computational Mathematics

UDC 378.225

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The guidelines contain instructions and recommendations concerning the structure and formatting of the Master's Thesis, explain the defense procedure and the grading system.

Recommended by the Scientific Council of the Faculty of Applied Mathematics and Informatics of Ivan Franko National University of Lviv on 23.12.2020, prot. No. 1.

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Contents

1. General principles

Master's Thesis is the final indicator of the student's readiness level for practical activities.

The Master's Thesis aims to consolidate the knowledge gained during the study process, to improve skills of independent work via applying original techniques to mathematical modeling of natural, economical, technological, etc. processes; programming algorithms for solving applied problems.

Master's Thesis must be of a scientific, practical, or innovative nature and reflect the scope of scientific or practical interests that the future specialist will be able to implement in his/her activities.

Master's Thesis in Apllied Mathematics must discuss problems and methods of applied and/or computational mathematics in their broad sense, such as mathematical modelling of physical, economical, social, biological, etc. processes; numerical and computational methods; computational science (geometry, linguistics, finance, biology, etc.); information engineering and other.

Master's Thesis is a qualification document, on its basis, the State Examination Committee determines the level of qualification of the specialist and his/her ability to work independently in the field of Applied Mathematics.

The structure and content of the Master's Thesis must be clear, with the logically sequential material presentation. A student should pay attention to the accuracy of formulations to avoid possible subjective or imprecise interpretation. A good manner is to strive for simplicity, clarity, and briefness. The author must ensure the novelty of the material, its scientific value, completeness of statements, and correctness of citing. Citing without references is forbidden.

Master's Thesis must be an independent scientific research work, with internal cohesion that reflects the development process and the achievements in the topic. Thus, the main requirements are:

- to be topical and correspond to the current level of scientific development;
- to fully justify the legitimacy and correctness of usage of all the research methods and techniques in every specific case;
- to contain a fundamentally new material, that includes a description of new facts, phenomena, and dependencies, or generalization of previously known principles from a novel point of view.

According to established scientific etiquette, the discussion is given in a third-person narrative such as "we believe", "in our opinion", etc. even if the document has a single author.

Typical structure of the Master's Thesis in Applied Mathematics includes:

1. cover page;
2. contents section;
3. abstract;
4. abbreviations section;
5. introduction;
6. the main part (usually divided into chapters, which consist of subchapters, or paragraphs);
7. conclusions;
8. references list;
9. annexes.

As a document presented for the defense, the Thesis package has to include additional documents, which we describe later.

2. Structural elements of the Introduction section

Introduction reveals the essence and the significance of the scientific problem, describes the grounds and the initial data for the development of the topic, current state of development by other researchers, justification of the need for current research. In the Introduction section, the author provides a general description of the work in the following order:

The relevance of the problem, which determined the choice of the research field. The expediency of the work should be grounded by analyzing the existing situation in the field and comparing it with known methods and solutions, which explicitly results in the development of the corresponding field of science.

The object of research – a process or a phenomenon under study that generates a problem.

The subject of research – some properties of the object of research, which a researcher needs to investigate.

Aim of the work and ***tasks,*** which a researcher has to solve to achieve the aim.

Research methods that were used to solve the tasks and achieve the aim.

Research materials – for the work in Applied Mathematics these usually are third-party software tools that were used to solve the tasks, datasets from third-party sources, etc.

Scientific novelty – a short annotation of new provisions or solutions, which the author personally proposes. It is obligatory to indicate the difference between these provisions and those already known.

Practical value of the results.

Approbation of the results (can be theoretical: conference reports or papers published).

3. Recommendations concerning the main part

If the work is mainly theoretical, the ***first chapter*** should contain a formulation of a mathematical model and a review of mathematical methods for solving the problem. It might be useful to provide examples of solving similar problems in the past, usually by other authors.

If the work is of more applied nature, the first chapter should contain the analysis of a subject area and a detailed description of the components of the system under investigation.

It is necessary to pay attention to the development of scientific views on the problem, to analyze up-to-date scientific achievements in the field. The student has to express his/her own opinion concerning existing views and provide his/her own assessment of well-known approaches to the problem.

The ***second chapter*** usually contains the analysis of the initial problem and its decomposition into local problems. The system connections are projected here, along with the algorithms and methods of solving local problems. For this purpose, one can use his/her own research results, which were obtained earlier in other works, as well as ideas, methodologies, and algorithms from other sources (books, articles, etc.)

If the work is theoretical, the main scientific ideas should go in this chapter, with explicit explanations and proofs. If the work is practical (e.g. applied software), the author should describe algorithms, architectural schemes, class diagrams, entity-relationship diagrams, and other illustrations that reveal decisions that were made. The source code should be attached as the annex to the Thesis.

In the ***third chapter*** of a Thesis, the author usually presents the value of the new ideas, provisions, or solutions, which were described in the second chapter. A good idea is to present some expository examples, which explicitly illustrate the benefits of using these ideas. The calculations should be illustrated with charts and diagrams. A comparison with alternative methods brings completeness to the research. One should not limit him(her)self with self-developed tools or methods – using well-known methods and trusted software ensures the validity of the results.

If a student presents his/her own software as part of the Thesis, the third chapter should contain a description of the user interface with screenshots and short guidelines for usage. The user manual, if it was created, should be added as an annex.

The chapters' structure we described should not be taken dogmatically. For example, one can devote the second chapter to an investigation of the problem from one point of view, and the third one – from another. The Thesis can consist of 4 or more chapters if necessary.

Conclusions. This is the final part of a Thesis, in which one should expose the scientific, practical, economic, or social value of the results. Also, the author should give the high-level assessment of the ideas presented, analyze his/her contribution to this specific research area, formulate general conclusions, suggestions, and practical recommendations, make a motivated forecast regarding the development of the problem in the future. Usually, charts, schemas, or tables are not relevant for this part.

The references list is an obligatory part of the Master's Thesis. It is a thematic systemized collection of bibliographic data about used, cited, and recommended literature. It may contain textbooks, manuals, journal articles, web resources, and other sources. The preferred order is according to referencing order throughout the Thesis; alphabetical order is also acceptable. The references list is given in the original language. Adding an item to the references list without referencing it from the main part of the Thesis is unacceptable.

Annexes should include auxiliary materials, which, if they were included in the main part of the Thesis, would litter the text. The auxiliary materials include intermediate mathematical considerations or calculations, software source code, user manuals, less relevant methodologies, which were developed, illustrations additional to those in the main part.

If the student has developed software, or its part, or introduced changes into existing source code, it is recommended to attach the listings as Annexes. It is not necessary to include all the source code, rather some snippets of important parts, for example:

- implementation of algorithms proposed by the author;
- interface definitions (if a digital library is proposed as a result);
- general framework structure;
- for some iterative methods – the outermost cycle of function calls.

Annexes are given in the order of referencing them throughout the Thesis and are numbered with capital Latin letters.

4. Instructions for the Master's Thesis formatting

Master's Thesis is a book-orientation document, page format A4, numbered in the heading of the page on the right. The total amount of pages should not be more than 80, including all tables, schemes, figures, annexes, etc.

The Thesis must be printed, not handwritten. The text must be printed in black color. Figures, diagrams, screenshots, illustrations, etc. can be colored.

All the pages must have Arabic numbers (except the cover page). The numbering is continuous, starting from the cover page and ending with the last page, including all the Figures, Tables, and Annexes. The cover page has number 1, thus the Contents page starts with number 2. The page number is placed in the upper right corner.

There are no strict demands regarding the **text formatting**, but the print must be convenient to read. The most widely used software for document editing are LaTeX and Microsoft Word. They can be used for Master's Thesis preparation, as well as any other software.

When working in **Microsoft Word**, as an example, the following formatting can be used:

- font – Times New Roman,
- line interval – 1.5,
- font size – 14 pt,
- paragraph size – 15-17mm (5-6 symbols),
- fields sizes: left – 30 mm, right – 15 mm, top – 15 mm, bottom – 20 mm.

Sample styles for formulas are the following:

- general settings: font – Times New Roman Cyr, 14 pt, indentation 0,5 cm, aligned to center, tabulation to the right 1,7 cm;
- Greek letters and special symbols: font – Symbol, 14 pt;
- indexes – 8 pt, subindexes – 7 pt.

LaTeX natively supports rendering mathematical expressions. For other tasks we recommend using the following packages, which became standard for scientific documents preparation:

- amsmath – for more complex mathematical expressions;
- biblatex – for bibliography management;
- babel – to meet language-specific typographical rules;
- graphics – for enhanced support for graphics;
- array – for extended array and tabular formatting.

Thesis chapters are ordered according to the contents section and each of them starts with a new page. Chapter titles are preceded with the word "Chapter" and the chapter number.

Subchapter titles are printed with the paragraph indentation without the dot sign in the end. If the title consists of several sentences, they are separated with a dot. Subchapter titles are printed in lowercase (except for the first letter – uppercase) and designated by the number of a chapter and a dot, e.g. "1.1." or "3.2.".

When using **formulas**, it is necessary to adhere to certain technical and spelling rules. The large, long, and cumbersome formulas, as well as those which contain summation, product, integral symbols, are subjects to place in a separate line. This also applies to all numbered formulas. To save some space, several short formulas of the same kind can be placed in one line, rather than in several lines. Small and simple formulas, which do not have some independent meaning, are given directly in the text. Meanings of the symbols and numerical coefficients have to be given right after the formula, one symbol, or coefficient per line. The first line of the meanings can start with the word "where" to preserve the readability of the text.

If the formula does not fit in one line, it should be wrapped after one of the following signs: equals (=), plus (+), minus (-), multiplication (x), division (:).

The formulas, that are referenced in the following text, should be numbered with Arabic numerals. Formula number consists of the chapter number and the number of the formula inside the chapter, divided by a dot. Formula number is aligned to right and given in brackets, e.g. (3.1) – the first formula in the third chapter. With multiline formulas, the number is given in the last line. If there is no room for the number in the line, one can move it to a new line. If the formula is in the frame, the number is given outside the frame on the right side opposite the central line of the formula.

Tables must be unified with a single style and numbered in order. Every table must be equipped with a header above it. A header starts with the word "Table" followed by a table number, which consists of a chapter number and the number of a table itself, e. g. "Table 1.3".

Usually, the table is placed straight after the first mentioning in the text. When wrapping the table onto the following page, the second title should be "Table 1.3 continued". If the cell is supposed to be empty, it is better to put the "–" sign for the explicit illustration of missed values. Every table should be accompanied by some short analysis or comment. An example of a table is given in Annex G.

All the **illustrations** (schemes, plots, diagrams, etc.) are referred to as Figures. The word *Figure* is usually abbreviated to Fig. They are designated by the number of the chapter and the number of the figure itself, for example, Fig. 3.1 – the first figure of the third chapter. After the number, the description of the figure is given. The examples of figures can be found in Annex H. When referencing a figure, one should give its full number. The figures should be placed immediately after referencing them in text.

The Thesis should not be oversaturated with illustrations.

A publication item of a ***reference list*** consists of two parts: a title (usually that is author's or authors' names) and a description. The description must contain information about the main title, the publisher, year of publishing, the serial number of the volume and issue (if applicable), number of pages. The University standard 73.1-02070987.02:2009 describes the recommended reference style; examples can be found in Annex I of these Guidelines. However, the student can consider using one of the well-known and established reference styles:

1. Chicago/Turabian;
2. Harvard;
3. APA (American Psychology Association);
4. MLA (Modern Language Association of America);
5. IEEE (Institute of Electrical and Electronics Engineers);
6. Vancouver;
7. Springer MathPhys.

The ***Annexes*** are numbered with capital Latin letters in the upper right corner, for example, "Annex D". If the Tables or Figures are present in the Annex, their numbers must include the Annex number instead of the Chapter number: Table A.1, Fig. C.3.

5. Preparation and procedure of defense

Master's Thesis package as a complex printed document, presented for the defense, must contain not only the Thesis itself, but also additional documents. Altogether, the package documents have to be presented in the following order:

1. cover page (see Annex A for the form);
2. student's assignment for the Master's Thesis (see Annex B for the form);
3. review page (see Annex C for the form);
4. approval page (see Annex D for the form);
5. evaluation sheet (see Annex E for the form);
6. materials of the Thesis (contents, abstract, abbreviations list, introduction, main part, conclusions, references, annexes).

Master's Thesis should be made in softcover, single-side, sewn on the left (except for review, conclusion, and evaluation sheets – simply put them inside), numbered in the heading of the page on the right.

The procedure of the defense of a Master's Thesis is defined by regulations provided by the Ministry of Education and Science of Ukraine and the Ivan Franko National University of Lviv.

A student is responsible for the Thesis to pass through the following steps:

1. to be signed by the Author and the Supervisor;
2. to receive Supervisor's Approval (Annex D);
3. to receive Departmental Approval (Annex D);
4. to receive Supervisor's Review (Annex E);
5. to receive Review from a third-party organization (Annex C);
6. to be defended at the Committee meeting.

In a due time defined by the Department, a student has to submit the printed and sewn Thesis to the Department along with the digital version of the Thesis and a software (if applies).

The Supervisor examines the Thesis and prepares the Approval according to the predefined template (Annex D).

In the Approval, the Supervisor states student's activity, initiative, creativity, level of independence, and readiness to work in the professional field. Also, the Approval must include estimation of the relevance of the topic of research, elements of novelty, the level of theoretical results, practical value, the validity of recommendations and proposals offered in the Thesis. At the end of the Approval, the Supervisor assertsand evaluates the Thesis, using a 4-level scale: "Excellent", "Good", "Satisfactory", "Unsatisfactory".

After discussion, the Department decides whether to allow the student to present the paper for the defense. If the Thesis is allowed for the defense, the Supervisor fills in the "Review of the scientific supervisor" section of the Evaluation sheet (Annex E) and chooses a Reviewer – a person with relevant knowledge and experience in the corresponding field. Usually, this is a professor from a different institution or a professional with an academic degree from some company or organization. Having examined the Assignment, Supervisor's Review and the Thesis, according to the template (Annex C), the Reviewer evaluates the content of the Thesis and the document itself, provides necessary comments and asserts the work, using a 4-level scale: "Excellent", "Good", "Satisfactory", "Unsatisfactory". A negative review is not a sufficient reason to reject the Thesis. The Department is eligible to organize and hold a preliminary defense of the Thesis.

Together with the Supervisor's Approval and the Reviews, a Master's Thesis has to be submitted to the Faculty Deanery in due time.

The Master's Thesis defense is held in a public meeting of a State Examination Committee. For this occasion, the student has to prepare a presentation: a speech, auxiliary materials, and responses to the Reviewer's remarks. Computer presentation

is the most suitable auxiliary material since it gives more tools to bring important information to the audience. The presentation must be short and precise. In the beginning, a student has to reveal the relevance of the topic, describe the problem, explain the choice of the research methods, and emphasize the novelty of his/her research. The main part of the presentation is devoted to the description of the research process itself, the methods that were used, and the results obtained. In the concluding part, it is necessary to justify the value of the results, provide recommendations for further development of the research, discuss possible practical application of the results.

The defense process follows several steps. First, the student presents his/her work (10-15 minutes). Then the Head of the Committee reads the external Review, and the student can give a response to the Reviewer's remarks. After that, the Committee members and any of the attendants can ask questions aiming to determine the student's qualification in the field of Applied Mathematics in general, and specifically in the subfield related to the topic of his/her Master's Thesis. The answers should be clear, with explicit reasoning, complete, but not too long, since the total time of the defense is usually limited to 20 minutes.

After the defense, the Committee members continue the discussion in private and assert every Master's Thesis. Different aspects are considered: the complexity of the tasks, the amount and value of the results, completeness and correctness of the answers, student's ability to present and defend his/her results both orally and in written form.

The Master's Thesis is graded using a 100 point scale, with the sybsequent convertion of the marks into the ECTS and a 4-level national system according to the following table:

100 point scale	ECTS	National system
90-100	A	"Excellent"
81-89	B	"Good"
71-79	C	"Good"
61-69	D	"Satisfactory"
51-59	E	"Satisfactory"
<51	F	"Unsatisfactory"

The total grade is the sum of the:

- score from the Supervisor (up to 20 points);
- score from the Reviewer (up to 30 points);
- score from the Committee (up to 50 points).

The students, who are willing to receive an Excellent grade, should make the results of their research to the scientific community, i. e. publish a paper in a corresponding scientific journal or participate in a relevant conference.

Annex A. *Cover page form*

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

IVAN FRANKO NATIONAL UNIVERSITY OF LVIV

Faculty of Applied Mathematics and Informatics

<Name of the Department>

Master's Thesis

<TOPIC OF THE THESIS>

Author: student of group <code of the group>
specialty 113 – Applied Mathematics

_____ <Last name> <First name>

Supervisor:

_____ <Last name> <First name>

Reviewer:

_____ <Last name> <First name>

Lviv – <year>

Annex B. *Form of Student's assignment for the Master's Thesis*

IVAN FRANKO NATIONAL UNIVERSITY OF LVIV

Faculty of Applied Mathematics and Informatics
<Name of the Department>
Specialty 113 – Applied Mathematics

<div align="center">

«APPROVE»
Head of the Department

_____

" ___ "_____ **20** ___

</div>

<div align="center">

S T U D E N T ' S   A S S I G N M E N T

FOR THE MASTER'S THESIS

<First name(s)> <Last name>

</div>

1. Topic of the Thesis: <Topic of the Thesis>,
supervisor <Degree> <Academic rank> <First name(s)> <Last name>
approved by the Academic council of the Faculty, protocol № <number>, date <date>.

2. Submission deadline: <date>.

3. Initial data for the work: <insert here models, methods, books, articles, software etc.>.

4. Outline of the work (list of tasks for implementation):

- <task>
- <task>

    ……

- <task>

5. List of obligatory graphic material (with exact indication of mandatory elements)

- <item>
- <item>

    ……

- <item>

6. Consultants (per chapter)

Chapter number	Name and position of the Consultant	Date and signature	
		Task was given	Task was accomplished

7. Assignment issue date: <date.month.year>.

CALENDAR PLAN

№	Stage title	Stage runtime	Notes
1		<from> — <to>	
2		<from> — <to>	
3		<from> — <to>	

Student: _____<First name(s)> <Last name>

Supervisor: _____<First name(s)> <Last name>

REVIEW
of the Master's thesis

Student: **<First name(s)> <Last name>**
Faculty of Applied Mathematics and Informatics

Topics (mark what applies):

☐ Computer modeling
☐ Numerical methods
☐ Mathematical modeling
☐ Optimization
☐ System programming
☐ Databases
☐ Educational software
☐ Web design
☐ Other

Maximum score	Student's grade	Criteria
6		Complexity and completeness of the research
6		Scientific novelty, elements of creativity
6		Autonomous work, systematic work
6		Quality and complexity of the theorems, software or algorithms

2		Scientific style, correct formulations
2		Illustrations
2		Compliance with thesis requirements
Total:		

Comments:

Reviewer: _____   _____
              Signature   First, last name

_____
                                Institution, position

Annex D. *Master's Thesis Supervisor's Approval form*

Master's Thesis
Supervisor's Approval

Student: **<First name(s)> <Last name>**

Supervisor: **<Degree> <Full name>**

"___"_____20____   _____
                                                                                        (signature)

Departmental Approval of the Master's thesis

The Master's thesis was discussed.
Student **<First name(s)> <Last name>** is allowed to present the Master's thesis to the examination committee for evaluation.

Head of the Department **<Degree> <Full name>**

"____"_____ 20____   _____
                                                                              (signature)

Annex E.   *Evaluation form*

EVALUATION SHEET
for the Master's thesis

Student: **\<First name(s)\> \<Last name\>**
Faculty of Applied Mathematics and Informatics

Assertion by the scientific supervisor

Topics (mark what applies):

☐ Computer modeling
☐ Numerical methods
☐ Mathematical modeling
☐ Optimization
☐ System programming
☐ Databases
☐ Educational software
☐ Web design
☐ Other

Maximum score	Student's grade	Criteria
4		Complexity and completeness of the research
4		Scientific novelty, elements of creativity
4		Autonomous work, systematic work
4		Quality and complexity of the software or algorithms

4		Scientific style, correct formulations Illustrations Compliance with thesis requirements
Total:		

Comments of the scientific supervisor:

Reviewer's grade _____.   **Grade for the defense _____.**   **TOTAL SUM _____.**

Head of the Committee: _____ _____
                          Signature   First, last name

Annex F. *Abbreviations page sample*

ABBREVIATIONS

FEM – Finite Element Method (a numerical method for solving problems of engineering and mathematical physics).

HTML – Hypertext Markup Language (the standard markup language for creating web pages and web applications).

m-file – MATLAB code file.

png – portable network graphic (a raster-graphics file-format that supports lossless data compression).

IT – Information Technologies (the use of computers to store, retrieve, transmit, and manipulate data).

dof – degrees of freedom (the number of parameters of the system that may vary independently).

Annex G. *Tables formatting samples*

Optimal values of the parameter α_* and the corresponding number of iterations n_* are given in Table 2.1 for different E_B/E_F – the ratio of Young modulus of the subdomains. To compare, we calculate the number of iterations n_g used by the gradient descent algorithm to solve the same problem.

Table 2.1.

Optimal values of the iteration parameter

$\dfrac{E_B}{E_F}$	*Problem A*			*Problem B*		
	α_*	n_*	n_g	α_*	n_*	n_g
0.125	0.7	6	4	0.6	8	8
0.25	0.5	9	6	0.42	12	10
0.5	0.35	14	8	0.27	18	14
1	0.23	20	12	0.16	32	24
2	0.135	40	18	0.089	62	42
4	0.073	70	32	0.047	116	72
8	0.038	124	54	0.0241	194	142

Table 2.2.

Stress concentration coefficients

K_t^A	K_t^{FEM}	K_t^{DDM}
3.04	3.031	3.044

Table 2.2 presents the values of the stress concentration coefficients, obtained with FEM (K_t^{FEM}) and DDM (K_t^{DDM}), compared to the analytical solution (K_t^A).

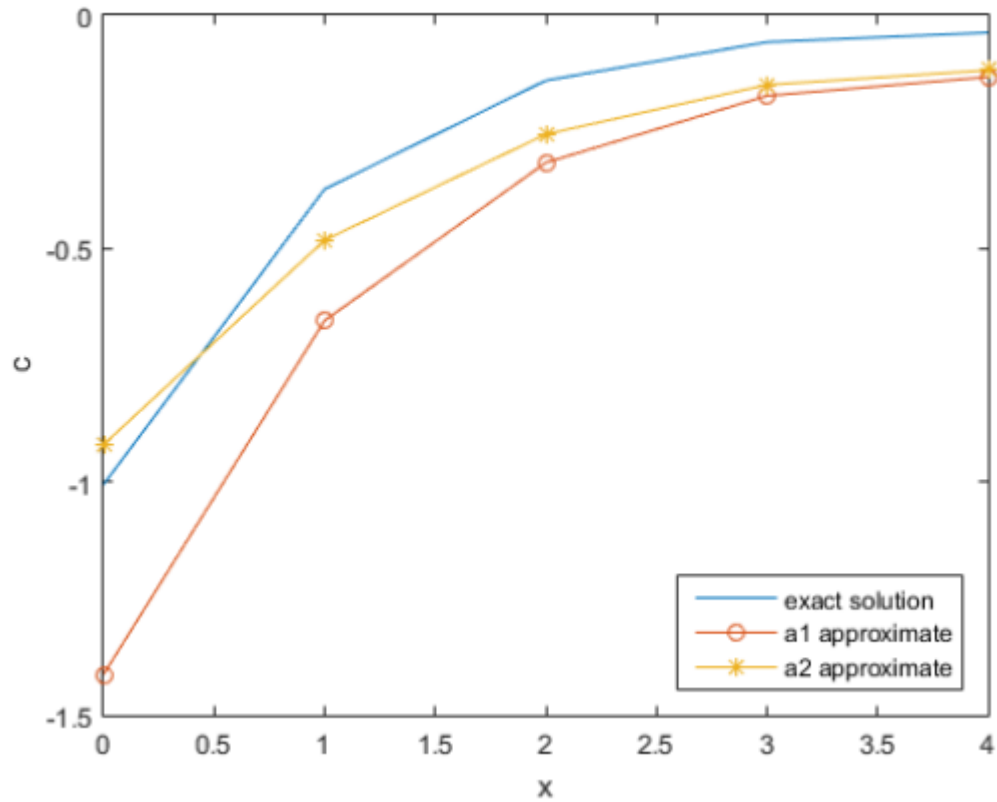Figures 7.1-7.3 illustrate numerical results for different sets of Neumann boundary conditions applied.

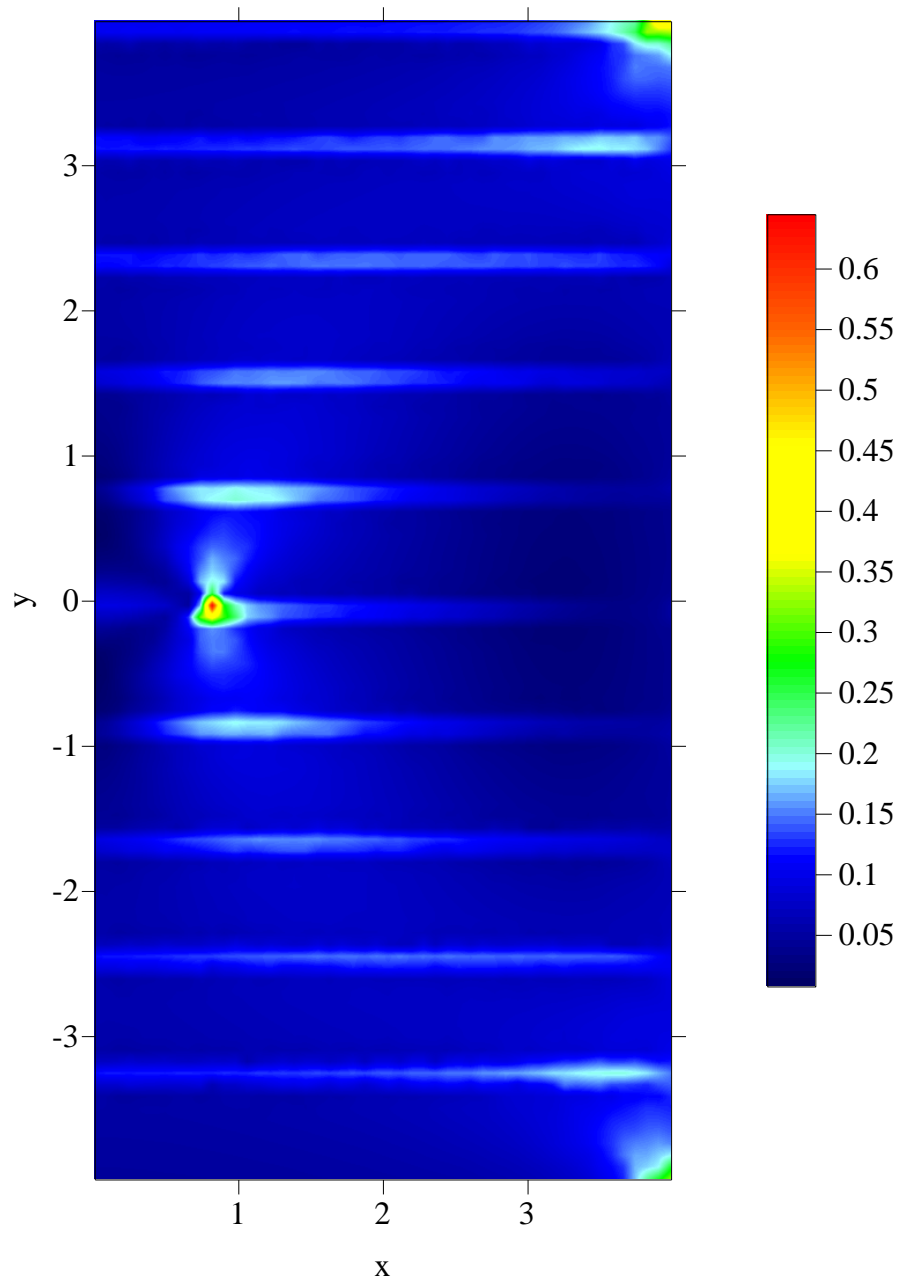Fig. 7.1. Numerical results, $q_1 = 1$, $q_2 = 0$.

Fig. 4.23. Von Mises Stress distribution.

Figure 4.23 depicts the distribution of von Mises stress values. One can see that the plasticity zone is localized near the tip of the crack.

Annex I.   *References samples*

Books with one, two or three authors

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3. Becker A. A. The Boundary Element Method in Engineering: a Complete Course / A. A. Becker. – McGraw-Hill, 1992. – 335 p.

4. Zienkiewicz O. C. The Finite Element Method. Vol. 1: The Basis / O. C. Zienkiewicz, R. L. Taylor. – Oxford: Butterworth & Heinemann, 2002. – 688 p.

Books with four or more authors

1. Stein E. et al. Error-controlled Adaptive Finite Elements in Solid Mechanics. – John Wiley & Sons. – 2002. – 192 p.

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Boundary Elements, Computational Mechanics Publishers. – 1998. – Ch. 2. – P. 33-84.

4. Savula Ya. H. Numerical modeling of ring-stiffened shells / Ya. H. Savula, K. Jarmai, I. S. Mukha // International Applied Mechanics. – 2008. – Vol. 11. – P. 132-142.

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1. Муха I. C. Наближене розвязування задач нелінійного деформування товстостінних гнучких тіл, покритих текстурою / I. Муха // Тези доповідей VI Всеукраїнської наукової конференції «Нелінійні проблеми аналізу». – Івано-Франківськ: Плай. – 2008. – с.72.

2. Savula Y. H. Computer Simulation the Problems of Mechanics for the Constructions with Thin Inclusions and Local Nonlinearity / Y. H. Savula, I. H. Makar, L. I. Vynnytska // Proceedings of the VII International Conference INTERPOR 2008. – Lubostron/Bydgoszcz. – 2008. – P. 33-34.

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