UNIVERSITY OF BUCHAREST
FACULTY OF MATHEMATICS AND COMPUTER SCIENCE
SCIENCE FIELD: ***MATHEMATICS***
MASTER PROGRAM (FULL-TIME): ***ALGEBRA, GEOMETRY AND CRYPTOGRAPHY***

Op.A31 Hopf Algebras

Name	**Hopf Algebras**			Code	**Op.A31**	
Year of study	II	Semester	1	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS		**5**
Total hours in curriculum	**42**	Total hours for individual study	**78**	Total hours per semester		**120**
Teacher(s)	Prof. Sorin Dascalescu					

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Algebra I, II, Rings and categories of modules
	Recommended	Groups and representations

Estimated time (hours per semester) for the required individual study				
1. Learning by using one's own course notes	**8**		8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**8**		9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**		10. Consultations	**5**
4. Research in library	**5**		11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**		12. Internet research	**8**
6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

<table>
<tr><td colspan="2">General competences (mentioned in MSc program sheet)</td></tr>
<tr><td rowspan="3">Specific competences</td><td>1.Knowledge and understanding
1. Knowledge and understanding of the concepts of algebra and its dual, coalgebra.
2. Understanding the relevance of representations.
3. Understanding the role of algebraic methods in geometry and analysis.</td></tr>
<tr><td>2. Instrumental
1. Ability to use mathematical methods studied in various previous courses for solving specific problems.
2. Understanding the importance of classification problems.</td></tr>
<tr><td>3. Attitudinal
1. to develop an interest for the field;
2. to realize the importance of Hopf algebra theory in contemporary mathematics
3. to assume an ethical conduct in scientific research;
4. to optimally valorise one’s own potential in scientific activities.</td></tr>
</table>

<table>
<tr><td>SYLLABUS</td><td>Lecture :
1. Algebras and coalgebras.
2. Modules and comodules.
3. Bialgebras and Hopf algebras.
4. Hopf modules.
5. Integrals for Hopf algebras.
6. Semisimple Hopf algebras.
7. Actions and coactions of Hopf algebras.
Tutorials :
1. Computation of dual (co)algebras.
2. Understanding sigma notation.
3. Checking Hopf algebra structures.
4. Finding integrals on certain Hopf algebras.
N.B. The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.</td></tr>
</table>

Bibliography	1. M. Sweedler, *Hopf Algebras*, Benjamin, New-York, 1969. 2. E. Abe, *Hopf Algebras*, Cambridge Univ. Press., 1977. 3. S. Dăscălescu, C. Năstăsescu, Ş. Raianu, *Hopf algebras: introduction*, Marcel Dekker, 2000 4. D. E. Radford, *Hopf Algebras*, World Scientific, 2012 5. Tomasz Brzezinski, Robert Wisbauer, *Corings and Comodules*, Series: London Mathematical Society Lecture Note Series (No. 309), Cambridge University Press, 2003. 6. Hazewinkel, Michiel; Gubareni, Nadiya; Kirichenko, V. V. *Algebras, rings and modules*. *Lie algebras and Hopf algebras.* Mathematical Surveys and Monographs, 168. American Mathematical Society, Providence, RI, 2010.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.A32 Lie Algebras

Name	**Lie Algebras**			Code	**Op.A32**		
Year of study	II	Semester	1	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**42**	Total hours for individual study		**78**	Total hours per semester		**120**
Teacher(s)	Prof. Dragoş Ştefan						

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Algebra I and Algebra II
	Recommended	

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**7**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**7**	9. Preparation for exam	**15**
3. Study of indicated bibliography	**14**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**4**	12. Internet research	**7**
6. Preparation of reports, small projects, homework	**7**	13. Other activities	**0**

7. Preparation for quizzes	**4**		14. Other activities	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Understanding of basic concepts of the theory Lie algebras. 2. Knowledge of the main properties of Lie algebras, especially nilpotence, solvability, and semisimplicity. 3. Knowledge of Lie algebra representations. 4. Knowledge and understanding of the Killing-Cartan classification of the finite dimensional simple Lie algebras.
	2. **Instrumental** 1. Ability to use formal mathematical language. 2. Ability to analyse and communicate mathematical methods and models. 3. To seek new sources of mathematical knowledge. 4. To be able to outline a problem in the field of study independently, to develop a solution method, to solve and to evaluate the results.
	3. Attitudinal 1. To develop an interest for the field; 2. To develop new mathematical skills; 3. To assume an ethical conduct in scientific research; 4. To be able to evaluate critically the obtained results.

SYLLABUS	**Lecture** *:* 1. The basic notions of Lie Algebras Theory. 2. Modules and representations. The classification of representations of **sl**(2, **C**). 3. Nilpotent Lie algebras, Engel Theorem. 4. Solvable Lie algebras, Lie Theorem. 5. Semisimple Lie algebras, the Killing form, Cartan's criteria. 6. Irreducible representations, Weyl Theorem. 7. Root systems, the root space decomposition. 8. The classification of semisimple Lie algebras (presentation of the main results, without proofs). **Tutorials :** 1. Examples of Lie algebras. 2. Explicit computations (Killing form, root system, Cartan matrice). **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. K. Erdmann, M. J. Wildon. *Introduction to Lie Algebras*. Springer (2006) 2. J.E. Humphreys. *Introduction to Lie Algebras and Representation Theory*, Graduate Texts în Mathematics. Springer (1997) 3. N. Jacobson. Lie algebras, Interscience Publishers (1961) 4. Ian M. Musson, *Lie Superalgebras and Enveloping Algebras*, American Mathematical Society, Providence, RI, 2012.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**70%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**0%**
- scientific reports, symposium etc	**10%**
- other activities (to be specified)	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.A33 Special Topics in Category Theory

Name	**Special Topics in Category Theory**			Code	**Op.A33**		
Year of study	II	Semester	1	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**42**	Total hours for individual study		**78**	Total hours per semester		**120**
Teacher(s)	Assoc. Prof. Daniel Bulacu						

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Rings and categories of modules; Algebra I, II
	Recommended	Braid Groups; Algebraic Topology

Estimated time (hours per semester) for the required individual study			
1. Learning by using one’s own course notes	**10**	Preparation of presentations.	**4**
2. Learning by using manuals, lecture notes	**10**	Preparation for exam	**16**
3. Study of indicated bibliography	**6**	10. Consultations	**6**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**6**

6. Preparation of reports, small projects, homework	**5**	13. Other activities…	**0**
7. Preparation for quizzes	**5**	14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78		

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between algebra, analysis and category theory. 2. Understanding the influence of category theory on Algebraic Topology and Topological Quantum Field Theory. 3. Ability to use categorical tools in algebra problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific categorical problems. 2. Ability to generalize results in algebra to the categorical settings.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of category theory in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Categories, functors and natural transformations. 2. Initial and final objects. Equalizers and coequalizers. 3. Adjoint functors. 4. Monoidal categories. Mac Lane's coherence theorem. 5. (Co)monads and (co)algebras in monoidal categories, and (co) representations. 6. The Eilenberg-Moore and Kleisli constructions associated to a monad. 7. Bimonads versus monoidal categories. Applications to categories of (co)representations. 8. Braided monoidal categories and braided functors. 9. The left and right centre constructions. **Tutorials :** 1. Examples and constructions ((co)limits, (co)products, etc.) 3. Adjoint functors versus (co)monads.

	4. Comparison between Moerdijk and Lack and Virelizier definitions for a bimonad. 5. Braided categories arising from different mathematical domains. 6. Explicit computations of some centers. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. C. Kassel, *Quantum Groups*, Springer-Verlang 1995. 2. C. Kassel, V. Turaev, *Braid Groups*, Springer-Verlag 2008. 3. F. Borceux, *Handbook of Categorical Algebra I*, Cambridge Univ. Press 2008. 4. S. Mac Lane, *Categories for the Working Mathematician*, second edition, Springer-Verlag 1998. 5. D. Bulacu, Algebras and Coalgebras in braided monoidal categories, Ed. Univ. Buc. 2009. 6. M. Kashiwara, P. Schapira, Categories and sheaves, Springer-Verlag 2005. 7. H. Simmons, *An Introduction to Category Theory*, Cambridge Univ. Press 2011.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam	**Correct solutions to all subjects in final exam. Correct solutions to homework problems.**

Average results to periodic/continuous testing.	**Successful presentations of scientific reports. Good results to periodic/continuous testing.**

Op. A34 Combinatorics in Commutative Algebra

Name	**Combinatorics in Commutative Algebra**			Code	**Op. A34**		
Year of study	II	Semester	1	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU – humanities							DF
Type{Ob – compulsory, Op – elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**42**	Total hours for individual study		**78**	Total hours per semester		**120**
Teacher(s)	Conf. Cornel Băeţica						

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Introduction to Commutative Algebra; Homological Algebra
	Recommended	Algebraic Curves; Introduction to Algebraic Topology

Estimated time (hours per semester) for the required individual study

1. Learning by using one's own course notes	**8**		8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**8**		9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**		10. Consultations	**5**
4. Research in library	**5**		11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**		12. Internet research	**8**
6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities…	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1. Knowledge and understanding** 1. Knowledge and understanding of the interplay between commutative algebra, combinatorics and topology. 2. Understanding the influence of combinatorics on the algebraic properties. 3. Ability to use the computational methods in commutative algebra problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific commutative algebra problems. 2. Ability to use the computer packages for solving problems in commutative algebra.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of commutative algebra in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

	Lectures 1. Regular sequences. Grade and depth. 2. Cohen-Macaulay rings and modules. 3. Systems of parameters. 4. Graded algebras over a field. 5. Hilbert series of graded algebras over a field. 6. Minimal graded free resolutions and graded Betti numbers.

SYLLABUS	7. Groebner bases. 8. Simplicial complexes. 9. Stanley-Reisner rings. **Tutorials** 1. Examples and conterexamples (regular sequences, Cohen-Macaulay rings, etc) 2. Computation of the Hilbert series of monomial ideals (with and without using a computer). 3. Explicit computations of minimal graded free resolutions, and finding the graded Betti numbers. 4. Computation of the Groebner bases of (graded) ideals (with and without using a computer). 5. Finding the f-vectors and h-vectors of simplicial complexes. 6. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. C. Băeţica, *Combinatorics of Determinantal Ideals*, Nova Science Publisher, 2006. 2. W. Bruns, J. Herzog, *Cohen-Macaulay Rings*, Cambridge University Press, 1998. 3. D. Eisenbud, *Commutative Algebra with a View Toward Algebraic Geometry*, Springer, 1995. 4. E. Miller, B. Sturmfels, *Combinatorial Commutative Algebra*, Springer, 2005.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**50%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homework	**30%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.A35 Analytic Methods in Number Theory

Name	**Analytic Methods in Number Theory**		Code	**Op.A35**	
Year of study	II	Semester 1	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities					DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS	**5**
Total hours in curriculum	**42**	Total hours for individual study	**78**	Total hours per semester	**120**
Teacher(s)	Assoc. Prof. Alexandru Gica				

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Elementary Number Theory; Calculus; Complex analysis
	Recommended	Algebraic Number Theory

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**8**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**5**

6. Preparation of reports, small projects, homework	**10**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

<table>
<tr><td colspan="2">General competences (mentioned in MSc program sheet)</td></tr>
<tr><td rowspan="3">Specific competences</td><td>1.Knowledge and understanding
1. Knowledge and understanding of the interplay between analysis, algebra and number theory.
2. Understanding the influence of analyticity on number theory problems.
3. Ability to use analytic tools in number theory problems.</td></tr>
<tr><td>2. Instrumental
1. Ability to use mathematical methods studied in various previous courses for solving specific number theory problems.
2. Ability to decide classification problems in number theory by using analytical tools.</td></tr>
<tr><td>3. Attitudinal
1. to develop an interest for the field;
2. to realize the importance of the field of analytic number theory in contemporary mathematics
3. to assume an ethical conduct in scientific research;
4. to optimally valorise one’s own potential in scientific activities.</td></tr>
</table>

<table>
<tr><td>SYLLABUS</td><td>Lecture :
1. Prime Number Theorem.
2. The Riemann zeta function.
3. Zero-free region for zeta function.
4. Riemann Hypothesis.
5. Prime numbers in arithmetical sequences. Dirichlet’s theorem.
6. Minkowski’s theorem of the convex body.
7. Schnirelmann density.
8. Circle method.
9. Analytical formulas for the class numbers
Tutorials :
1. Bernoulli numbers.
7. Connection with the values of zeta Riemann function.
8. Sums of three squares (Gauss’s theorem).
9. Application to Waring’s problem.
10. Vinogradov’s theorem.
N.B. The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.</td></tr>
</table>

Bibliography	1. Gica A., Panaitopol L., *Probleme celebre de teoria numerelor*, Editura Universităţii Bucureşti, 1998. 2. Jean-Marie De Koninck, Florian Luca, *Analytic Number Theory: Exploring the Anatomy of Integers* (Graduate Studies in Mathematics), AMS, 2012. 3. Henryk Iwaniec and Emmanuel Kowalski, *Analytic Number Theory*, American Mathematical Society, Providence, RI, 2004.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**40%**
- results to mid-term examination (oral, optional)	**0%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.G31 Algebraic Geometry

<table>
<tr><td>Name</td><td colspan="3">Algebraic Geometry</td><td>Code</td><td colspan="2">Op.G31</td></tr>
<tr><td>Year of study</td><td>II</td><td>Semester</td><td>1</td><td colspan="2">Assessment (E/V/C)</td><td>E</td></tr>
<tr><td colspan="6">Formative category:
DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities</td><td>DF</td></tr>
<tr><td colspan="4">Type{Ob – compulsory, Op- elective, F – optional}</td><td>Op</td><td>ECTS</td><td>5</td></tr>
<tr><td>Total hours in curriculum</td><td>42</td><td colspan="2">Total hours for individual study</td><td>78</td><td>Total hours per semester</td><td>120</td></tr>
<tr><td>Teacher(s)</td><td colspan="6">Assoc. Prof. Cristian Voica</td></tr>
</table>

<table>
<tr><td>Faculty</td><td>Mathematics and Computer Science</td><td rowspan="5"></td><td colspan="5" rowspan="3">Total hours per semester in curriculum</td></tr>
<tr><td>Department</td><td>Mathematics</td></tr>
<tr><td>Main domain
(sciences, art, culture)</td><td>Exact Sciences</td></tr>
<tr><td>Domain of master program</td><td>Mathematics</td><td>Total</td><td>C</td><td>S</td><td>L</td><td>P</td></tr>
<tr><td>Program name</td><td>Algebra, Geometry and Cryptography</td><td>42</td><td>28</td><td>14</td><td></td><td></td></tr>
</table>

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Differential Geometry on Manifolds; Complex analysis
	Recommended	Sheaf Theory; Algebraic Topology

<table>
<tr><td colspan="5">Estimated time (hours per semester) for the required individual study</td></tr>
<tr><td>1. Learning by using one’s own course notes</td><td>8</td><td></td><td>8. Preparation of presentations.</td><td>3</td></tr>
<tr><td>2. Learning by using manuals, lecture notes</td><td>8</td><td></td><td>9. Preparation for exam</td><td>16</td></tr>
<tr><td>3. Study of indicated bibliography</td><td>10</td><td></td><td>10. Consultations</td><td>5</td></tr>
<tr><td>4. Research in library</td><td>5</td><td></td><td>11. Field research</td><td>0</td></tr>
<tr><td>5. Specific preparation for practicals/tutorials</td><td>5</td><td></td><td>12. Internet research</td><td>8</td></tr>
</table>

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between analysis, geometry and topology. 2. Understanding the influence of analyticity on geometric properties. 3. Ability to use complex analytic tools in geometry problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific geometric problems. 2. Ability to decide classification problems in geometry by using algebraic tools.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of complex geometry in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Affine and quasi-affine varieties: regular functions, rational functions, the birational viewpoint. 2. Local theory: the Krull dimension, regularity, consequences of the factoriality of regular local rings. 3. Projective varieties; the Segre and Veronese maps. Projective varieties are proper. 4. Projections and correspondences. 5. Divisors and the canonical class. 6. Coherent and quasi-coherent sheaves. The cohomology of projective varieties. 7. Intersection theory on surfaces; the Riemann-Roch theorem, blowing-up, the intersection form of the blown-up surface. 8. The language of schemes. Varities over finite fields. **Tutorials :** 1. Examples and constructions of varieties, regular and rational functions. 2. Explicit dimension computations, exercises involving factoriality

	and regularity 3. Examples of projective varieties, consequences of Veronese embeddings. 4. Explicit characterisations of linear projections. 5. Divisorial computations. 6. Verification of coherence in specific examples. Cohomology of particular examples of projective varieties. 7. Applications of intersection theory on surfaces. 8. Explicit examples of schemes, the ring of dual numbers, tangent vectors. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.
Bibliography	1. J. Harris, *Algebraic Geometry*, Springer, 1992. 2. R. Hartshorne, *Algebraic Geometry,* Springer 1977. 3. G. Kempf, *Algebraic Varieties*, Cambridge, 1993. 4. Igor V. Dolgachev, *Classical Algebraic Geometry: A Modern View*, Cambridge University Press, 2012 5. David A. Cox, John B. Little, Donald O'Shea, *Using Algebraic Geometry*, Springer, 2005 6. Brendan Hassett, *Introduction to Algebraic Geometry*, Cambridge University Press, 2007 7. Thomas A. Garrity, Richard G. Belshoff, Lynette Boos, J. Ryan Brown, Carl Lienert, *Algebraic Geometry: A Problem Solving Approach*, AMS, 2013
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)

Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.G32 Complex Geometry

Name	**Complex Geometry**			Code	**Op.G32**	
Year of study	II	Semester	1	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS	**5**
Total hours in curriculum	**42**	Total hours for individual study		**78**	Total hours per semester	**120**
Teacher(s)	Prof. Liviu Ornea					

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Differential Geometry on Manifolds; Complex analysis
	Recommended	Sheaf Theory; Algebraic Topology

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between analysis, geometry and topology. 2. Understanding the influence of analyticity on geometric properties. 3. Ability to use complex analytic tools in geometry problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific geometric problems. 2. Ability to decide classification problems in geometry by using complex analytic tools.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of complex geometry in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Complex manifolds. 2. Complex and holomorphic fibre bundles. 3. Hermitian manifolds. 4. The Chern connection. 5. Chern-Weil theory. 6. Kaehler manifolds. 7. Introduction in Hodge theory. 8. Calabi-Yau and Kaehler-Einstein manifolds. 9. Submanifolds. **Tutorials :** 1. Examples and constructions (products, holomorphic actions etc.) 2. Projective and Grassmann spaces, tautological bundles. 3. Explicit computations of Chern classes. 4. Hopf manifolds. 5. Holonomy. Hyperkaehler manifolds.

	N.B. The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. P. Griffith, J. Harris, Principles of algebraic geometry, Wiley, 1994. 2. A. Moroianu, Lectures on Kaehler manifolds, Cambridge Univ. Press, 2007 3. W. Ballmann, Lectures on Kaehler manifolds, E.M.S., 2006
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.G33 Lie Groups

Name	**Lie Groups**			Code	**Op.G33**	
Year of study	II	Semester	1	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS	**5**
Total hours in curriculum	**42**	Total hours for individual study		**78**	Total hours per semester	**120**
Teacher(s)	Prof. Gabriel Pripoae					

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Differential Geometry on Manifolds; Real Analysis; Linear Algebra
	Recommended	Riemannian Geometry. Algebraic Topology

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**
6. Preparation of reports, small projects, homework	**5**	13. Other activities…	**0**

7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between algebra and geometry. 2. Understanding the role of symmetry in differential geometry and in physics. 3. Ability to use algebraic and linear algebra tools in differential geometry problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific geometric problems. 2. Ability to recognize the importance of symmetry in differential equations, geometry and physics and use it to solve specific problems.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of geometry in all its appearances in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Lie groups and Lie algebras. Definitions. Examples. 2. Left invariant fields and forms. 3. The exponential map. 4. Local Lie groups. 5. Lie subgroups and quotient groups. Homogeneous spaces. 6. Lie's 3rd theorem (global form). 7. Compact Lie groups. 8. Elements of reprezentation theory. **Tutorials :** 1. Analiticity of Lie groups morphisms. 2. Explicit computation on matrix groups. 3. Adjoint and coadjoint representations. 4. Symmetry groups of differential equations. 5. Symmetric spaces. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. J.J. Duistermaat, J.A. Kolk, *Lie groups*, Springer, 2000. 2. S. Helgason, *Differential geometry and symmetric spaces*, AMS Chelsea Publ., 2001. 3. A. Kirillov, An introduction to Lie groups and Lie algebras, Cambridge Univ. Press 2008 4. C. Procesi, Lie groups. An approach through invariants and representations, Springer 2007.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.G34 Submanifolds of Riemannian Manifolds

Name	**Submanifolds of Riemannian Manifolds**		Code	**Op.G34**		
Year of study	II	Semester	1	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS		**5**
Total hours in curriculum	**42**	Total hours for individual study	**78**	Total hours per semester		**120**
Teacher(s)	Prof. Ion Mihai					

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Differential Geometry on Manifolds; Riemannian geometry
	Recommended	Complex geometry

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the relation between the geometry of submanifolds and the geometry of the ambient space. 2. Understanding how Riemannian invariants obstruct the existence of certain type of submanifolds.
	2. Instrumental 1. Ability to use mathematical and topological methods studied in various previous courses for solving specific Riemannian geometric problems. 2. Ability to decide classification problems in geometry by using Riemannian invariants.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of Riemannian geometry in contemporary mathematics; 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Submanifolds in Riemannian manifolds. Gauss and Weingarten formulae. Gauss, Codazzi and Ricci equations. 2. Totally geodesic submanifolds, minimal submanifolds, totally umbilical submanifolds. 3. Invariants of Riemannian manifolds: scalar curvature, Ricci curvature, Chen invariants. 4. Optimal geometric inequalities for Riemannian invariants of submanifolds in constant curvature spaces. 5. Applications: obstructions to the existence of minimal submanifolds, classification theorems of ideal submanifolds. 6. Special classes of submanifolds in Hermitian manifolds: complex submanifolds, Lagrangian submanifolds, slant submanifolds, CR-submanifolds.. **Tutorials :** 1. Examples and constructions in real space forms.

	2. Explicit computations of Chen invariants. 3. Examples of CR submanifolds 4. Examples of slant submanifolds. 5. Other metric structures (Sasakian, cosymplectic etc.) and their submanifolds. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. D. Blair, *Riemannian Geometry of Contact and Symplectic Manifolds*, Birkhauser, 2010. 2. B.Y. Chen, *Geometry of Submanifolds,* M. Dekker, 1973. 3. B.Y. Chen, *Pseudo-Riemannian Geometry, Delta Invariants and Applications,* World Scientific, 2011. 4. S. Kobayashi, K. Nomizu, *Foundations of Differential* Geometry, vol. II, Wiley-Interscience, 1969. 5. I. Mihai, *Geometria Subvarietăților în Varietăți Complexe,* Editura Universității din București, 2002. 6. I. Mihai, A. Mihai, V. Ghișoiu, *Culegere de Probleme de Geometrie Diferențială,* Editura Universității din București, 2012.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.G35 Differential Topology

<table>
<tr><td>Name</td><td colspan="3">Differential Topology</td><td>Code</td><td colspan="2">Op.G35</td></tr>
<tr><td>Year of study</td><td>II</td><td>Semester</td><td>1</td><td colspan="2">Assessment (E/V/C)</td><td>E</td></tr>
<tr><td colspan="6">Formative category:
DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities</td><td>DF</td></tr>
<tr><td colspan="4">Type{Ob – compulsory, Op- elective, F – optional}</td><td>Op</td><td>ECTS</td><td>5</td></tr>
<tr><td>Total hours in curriculum</td><td>42</td><td colspan="2">Total hours for individual study</td><td>78</td><td>Total hours per semester</td><td>120</td></tr>
<tr><td>Teacher(s)</td><td colspan="6">Prof. Liviu Ornea, Assoc. Prof. Victor Vuletescu</td></tr>
</table>

<table>
<tr><td>Faculty</td><td>Mathematics and Computer Science</td><td rowspan="5"></td><td colspan="5" rowspan="3">Total hours per semester in curriculum</td></tr>
<tr><td>Department</td><td>Mathematics</td></tr>
<tr><td>Main domain
(sciences, art, culture)</td><td>Exact Sciences</td></tr>
<tr><td>Domain of master program</td><td>Mathematics</td><td>Total</td><td>C</td><td>S</td><td>L</td><td>P</td></tr>
<tr><td>Program name</td><td>Algebra, Geometry and Cryptography</td><td>42</td><td>28</td><td>14</td><td></td><td></td></tr>
</table>

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Differential Geometry on Manifolds; Algebraic Topology
	Recommended	Sheaf Theory; Riemannian Geometry

<table>
<tr><td colspan="5">Estimated time (hours per semester) for the required individual study</td></tr>
<tr><td>1. Learning by using one's own course notes</td><td>8</td><td></td><td>8. Preparation of presentations.</td><td>3</td></tr>
<tr><td>2. Learning by using manuals, lecture notes</td><td>8</td><td></td><td>9. Preparation for exam</td><td>16</td></tr>
<tr><td>3. Study of indicated bibliography</td><td>10</td><td></td><td>10. Consultations</td><td>5</td></tr>
<tr><td>4. Research in library</td><td>5</td><td></td><td>11. Field research</td><td>0</td></tr>
<tr><td>5. Specific preparation for practicals/tutorials</td><td>5</td><td></td><td>12. Internet research</td><td>8</td></tr>
</table>

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between analysis, geometry and topology. 2. Understanding the influence of topology on differential and geometric properties.
	2. Instrumental 1. Ability to use differential forms in topology. 2. Ability to decide classification problems in differential geometry by using topological tools.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of algebraic topology in contemporary mathematics; 3. to realize the unity of algebra, geometry and analysis; 4. to assume an ethical conduct in scientific research; 5. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Differentiable manifolds (with boundary). 2. Sard theorem. 3. Orientation. Brouwer degree. 4. Transversality. Whitney embedding theorem. 5. Intersection theory. Applications. 6. Lefschetz fixed point theorem. 7. Vector fields. Index. Poincaré-Hopf theorem. **Tutorials :** 1. Morse functions. Examples. 2. Review of Stokes theorem. Computations. 3. Cohomology. Duality. 4. Fibre bundles. Chern classes. The splitting principle. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. V. Guillemin, A. Pollack, *Differential topology*, Chelsea Publ., 2010 2. M.W. Hirsch, *Differential topology*, GTM 33, Springer, 1994. 3. J. Milnor, *Topology from the differentiable viewpoint*, Princeton Univ. Press, 1997 4. A.R. Shastri, *Elements of differential topology*, CRC Press, Boca Raton, 2011. 5. A. Wallace, *Differential topology. First steps*, Dover Publications, 2006.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.C31 Computational Cryptography

Name	Computational Cryptography			Code	**Op.C31**	
Year of study	II	Semester	2	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS		**5**
Total hours in curriculum	**42**	Total hours for individual study	**78**	Total hours per semester		**120**
Teacher	Assoc. Prof. Catalin Gherghe					

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Number Theory General Probability
	Recommended	Projective Geometry

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the utility of knowledge in number theory, probability and geometry in cryptography 2. Understanding the construction of various cryptosystems.
	2. Instrumental 1. Ability to use methods from number theory, discrete geometry, and probability for breaking various cyphers. 2. Ability to encrypt and decrypt various cryptosystems.
	3. Attitudinal 1. To develop an interest for the field. 2. To realize the importance of the field of cryptography. 3. To assume an ethical conduct in scientific research. 4. To optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Classical cryptosystems and theirs cryptanalysis. (Caesar, Vigenere, Hill). 2. Symmetric cryptosystems (Data Ecryption Standard, Advanced Encryption Standard). 3. Perfect security. Shannon's theorem. One Time Pad cipher. 4. Public key cryptography. General theory. Diffie-Hellman protocol. 5. RSA (Description and attack methods). 6. Lattices in Cryptography 7. Rabin cryptosystem. 8. ElGamal cryptosystem. 9. Knapsack cryptosystem (attack using Geometry of Numbers). 10. Hash functions. Digital signatures. Authentication. 11. Elliptic curves cryptography (Diffie-Hellman protocol, RSA, ElGamal, Menezes-Vansone). 12. Quantum cryptography. BB protocols. **Tutorials :** 1. Examples of attacks using frequency analysis. 2. Concrete examples of encryptions and decryption. 3. Concrete applications of algorithms.

	4. Computations on elliptic curves. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. J.Hoffstein, J.Pipher, J.H.Silverman: An Introduction to Mathematical Cryptography, Springer, 2010. 2. D.R. Stinson: Cryptography: Theory and Practice, (Chapman and Hall), 2006 3. B. Schneier: Schneier's Cryptography Classics Library: Applied Cryptography, Secrets and Lies, and Practical Cryptography, Wiley, John & Sons, 2007
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.C32 Elliptic Curves

Name	**Elliptic curves**			Code	**Op.C32**		
Year of study	II	Semester	1	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**42**	Total hours for individual study		**78**	Total hours per semester		**120**
Teacher(s)	Assoc. Prof. Victor Vuletescu						

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Algebraic curves:; Sheaf theory
	Recommended	Complex functions; Complex manifolds; Algebraic number theory

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between algebra, geometry and topology. 2. Understanding the influence of working over finite fields on geometric properties. 3. Ability to use complex analytic tools in geometry problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific geometric problems. 2. Ability to apply various theoretical results to practical problems in cryptography.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of complex geometry in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.
SYLLABUS	**Lecture** *:* 1. Algebraic curves; regular functions, rational functions, the Riemann-Roch theorem. 2. The geometry of elliptic curves: the Weierstrass normal form, the group law, isogenies. 3. Elliptic curves over the filed of complex numbers: Weierstrass parameterisation, the division polynomials. 4. Invariants of elliptic curves: the Tate module, the Weil pairing. The formal group of an elliptic curve. 5. Elliptic curves over finite fields; Hasse's theorem, the endomorphism ring, supersingular curves. 6. Applications. Counting points of an elliptic curve over a finite field. Elliptic curves over a commutative finite ring. **Tutorials :** 1. Finite fields and elements of Galois theory 2. Study of concrete examples of elliptic curves 3. Modular functions 4. Other methods of counting points of elliptic curves 5. The MOV attack and Rueck-Frey attack. **N.B.** The above is a description of the topics to be covered and are not in

	1-1 correspondence with the 14 lectures/tutorials.
Bibliography	1. Silverman, J. , The arithmetic of elliptic curves. GTM 106, Second edition, Springer, Dordrecht, 2009. 2. Washington, L., Elliptic curves. Number theory and cryptography. Discrete Mathematics and its Applications (Boca Raton). Chapman & Hall, 2003 3. Ekedahl, T., One semester of elliptic curves. EMS Series of Lectures in Mathematics.*European Mathematical Society (EMS), Zürich,* 2006
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.C33 Algebraic Number Theory with Applications to Cryptography

Name	**Algebraic Number Theory with Applications to Cryptography**			Code	**Op.C33**		
Year of study	II	Semester	1	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**42**	Total hours for individual study		**78**	Total hours per semester		**120**
Teacher(s)	Assoc. Prof. Alexandru Gica						

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**42**	**28**	**14**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Basic Algebra; Elementary Number Theory
	Recommended	Analytic Number Theory; Class Field Theory

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**7**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**7**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**	10. Consultations	**8**
4. Research in library	**5**	11. Field research	**0**

5. Specific preparation for practicals/tutorials	**4**		12. Internet research	**8**
6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 78			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between algebra and number theory. 2. Ability to use algebraic tools in number theory problems. 3. Understanding the most important factorization algorithm, Number Field Sieve.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific number theory problems. 2. Ability to decide classification problems in number theory by using algebraic tools.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of algebraic number theory in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Algebraic Number Fields; 2. Quadratic and cyclotomic fields; other examples. 3. Rings of Algebraic Integers. 4. Integral basis and discriminant. 5. Dedekind's domains. 6. The group of the class ideals is finite. 7. Units. Dirichlet's theorem. 8. Applications in solving Diophantine equations. 9. NFS (Number Field Sieve) **Tutorials :** 1. Norm, trace, discriminant. 2. How to find the integral basis. 3. Algorithms for computing class numbers. 4. Algorithms for finding the units. 5. How to implement NFS. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. G.J. Janusz, *Algebraic number fields*, AMS, 1996. 2. J.W.S Cassels, A. Frohlich, *Algebraic Number Theory*, London Mathematical Society, 2010 3. K. Kato, Number Theory 2, Introduction to Class Field Theory, AMS, 2011
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**40%**
- results to mid-term examination (oral, optional)	**0%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.A41 Computational Algebra

Name	**Computational Algebra**		Code	**Op.A41**	
Year of study	II	Semester 2	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities					DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS	**5**
Total hours in curriculum	**30**	Total hours for individual study	**90**	Total hours per semester	**120**
Teacher(s)	Lect. Marius Vladoiu				

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**5**	**5**	

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Algebra I,II, basic Galois theory, basic Algebraic Geometry for geometric versions of the algebraic computations
	Recommended	Commutative Algebra

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**10**	8. Preparation of presentations.	**5**
2. Learning by using manuals, lecture notes	**5**	9. Preparation for exam	**20**
3. Study of indicated bibliography	**10**	10. Consultations	**10**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**10**

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between commutative algebra and combinatorics, and their computational aspects. 2. Knowledge and understanding of the algorithmic aspects of the computation of algebraic/homological invariants. 3. Ability to use mathematical software for research.
	2. Instrumental 1. Ability to use computer algebra software for learning, verifying theorems/conjectures.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the crucial importance of the computer algebra software in the modern research; 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.
SYLLABUS	**Lecture** *:* 1. Gröbner bases: monomial ideals and operations, monomial orders, initial ideals, Macaulay's theorem, the division algorithm in the polynomial ring with n indeterminates, Buchberger's criterion for computing a Gröbner basis, reduced Gröbner bases and their uniqueness, the universal Gröbner basis of an ideal. 2. Elimination theory and its applications: elimination monomial orders, Elimination's theorem, algortihms for computing: intersection of ideals, quotient of ideals, saturation of an ideal, ideal membership, radical membership, kernel and image of a K-algebra homomorphism, algebra membership, homogenization. Hilbert's Nullstellensatz. Equivalent characterization of the zero-dimensional ideals. 3. Gröbner bases for modules. Construction of graded free resolutions. Computational proof of Schreyer for the Hilbert's Syzygy theorem. **Tutorials :** 1. Applications of Gröbner bases: computation of the reduced row-echelon form of a matrix, the fundamental theorem of symmetric polynomials, computation of a minimal polynomial of an element from a simple algebraic extension of a finite field or Q, solvability of

	systems of polynomial equations with complex coefficients (deciding solvability, existence of a finite number of solutions, and in this case giving upper bounds of this number), graph colorings and solving Sudoku, computation of algebraic invariants of a homogeneous ideal (Krull dimension, Hilbert function, Hilbert series and Hilbert polynomial, (minimal) free resolutions). **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 10 lectures/tutorials.

Bibliography	1. D. Cox, J. Little, D. O'Shea - Ideals, Varieties and Algorithms, Springer, 3rd edition, 2007. 2. G.M. Greuel, G. Pfister - A Singular Introduction to Commutative Algebra, Springer, 2nd edition, 2008. 3. V. Ene, J. Herzog - Grobner bases în Commutative Algebra, Amer. Math. Soc., vol. 130, 2011. 4. Jurgen Herzog, Takayuki Hibi - Monomial Ideals, Springer, 2010. 5. M. Kreuzer, L. Robbiano - Computational Commutative Algebra 1, Springer, 2000. 6. M. Kreuzer, L. Robbiano - Computational Commutative Algebra 2, Springer, 2005.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**50%**
- hands-on lab test&quiz	**20%**
- results to periodic tests/quizzes/homeworks	**10%**
- results to mid-term examination (oral, optional)	**10%**
- scientific reports, symposium etc	**10%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions for all indicated subjects in final exam or correct solutions (for mark	**Correct solutions to all subjects in final exam. Correct solutions to homework problems.**

5) and Average results to periodic/continuous testing.	**Successful presentations of scientific reports. Good results to periodic/continuous testing.**

Op.A42 An Introduction to Quantum Group Theory

Name	**An Introduction to Quantum Group Theory**			Code	**Op. A42**		
Year of study	II	Semester	2	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**30**	Total hours for individual study		**90**	Total hours per semester		**120**
Teacher(s)	Assoc. Prof. Daniel Bulacu						

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**					
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**	Total	C	S	L	P	
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**10**			

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Hopf algebras; Category theory
	Recommended	Lie algebras; Algebraic topology

Estimated time (hours per semester) for the required individual study			
1. Learning by using one’s own course notes	**8**	8. Preparation of presentations.	**6**

2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**8**	10. Consultations	**6**
4. Research in library	**8**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**8**	12. Internet research	**6**
6. Preparation of reports, small projects, homework	**8**	13. Other activities…	**0**
7. Preparation for quizzes	**8**	14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90		

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between category theory, Hopf algebra theory and algebraic topology. 2. Understanding the influence of quantum groups in solving mathematical-physics problems. 3. Ability to use Hopf algebra and Lie algebra tools in quantum group problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific algebraic problems. 2. Ability to make connections between quantum group theory and Hopf algebra and Lie algebra theory, respectively.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of quantum groups in contemporary mathematics; 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.
	Lecture *:* 1. The quantum plane and its symmetries. 2. The quantum groups GLq(2) and SLq(2). 3. The quantum enveloping algebra of sl(2). 4. (Co)Quasitriangular Hopf algebras. 5. Categories of Yetter-Drinfeld modules. 6. Drinfeld's quantum double. 7. The FRT construction. Applications. 8. Quantum groups defined by actions and coactions of a Hopf

SYLLABUS	algebra on an algebra, respectively on a coalgebra. **Tutorials :** 1. Examples and constructions (bialgebra structures, actions, coactions, etc.) 2. Lie algebras and enveloping algebras. 3. Explicit computations of some Harish-Chandra homomorphisms. 4. Representation-theoretic interpretation of the quantum double. 5. Bicrossed products of groups and bialgebras.
Bibliography	1. C. Kassel, *Quantum Groups*, Springer-Verlang 1995. 2. Lambe şi D. Radford, *Introduction to the quantum Yang-Baxter equation and quantum groups*, Kluwer Academic Publishers 1997. 3. S. Majid, *Foundations of quantum groups theory*, Cambridge Univ. Press 1995. 4. D. E. Radford, *Hopf Algebras*, World Scientific 2012 5. D. Bulacu, *Algebras and coalgebras in braided monoidal categories*, Ed. Univ. Buc. 2009. 6. Susumu Ariki, Hiraku Nakajima, Yoshihisa Saito, *Algebraic Groups and Quantum Groups*, AMS 2012.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.A43 Representation Theory of Algebras

Name	**Representation Theory of Algebras**			Code	**Op.A43**	
Year of study	II	Semester	1	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS		**5**
Total hours in curriculum	**30**	Total hours for individual study	**90**	Total hours per semester		**120**
Teacher(s)	Prof. Sorin Dascalescu					

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Algebra I, II, Rings and categories of modules, Groups and representations
	Recommended	Lie Algebras

Estimated time (hours per semester) for the required individual study			
1. Learning by using one’s own course notes	**8**	8. Preparation of presentations.	**8**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**18**
3. Study of indicated bibliography	**10**	10. Consultations	**10**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the concept of representation. 2. Understanding certain classification results and their relevance.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific problems. 2. Understanding the importance of knowing the representations of an object.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of Representation Theory in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Projective modules over artinian algebras. The structure of artinian algebras. 2. Algebras of finite representation type. The Brauer-Thrall conjectures. 3. Representations of quivers. The quiver algebra. 4. Gabriel's Theorem. **Tutorials :** 1. Description of projectives over certain algebras. 2. Explicit description of representations of certain quivers. 3. Discussing the representation type of certain algebras. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 10 lectures/tutorials.

Bibliography	1. P. Etingof et al., *Introduction to representation theory*, AMS, 2011. 2. C. Curtis, I. Reiner, Representation theory of finite groups and associative algebras, AMS, 2006. 3. R. S. Pierce, Associative algebras, Springer Verlag, 1982.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.A44 Valuation Theory and Local Fields

Name	**Valuation Theory and Local Fields**			Code		**Op.A44**	
Year of study	II	Semester	2	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**30**	Total hours for individual study		**90**	Total hours per semester		**120**
Teacher(s)	Prof. Victor Alexandru						

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**					
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**	Total	C	S	L	P	
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**10**			

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Field Theory, Elementary Number Theory
	Recommended	Galois Theory

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**10**	8. Preparation of presentations.	**5**
2. Learning by using manuals, lecture notes	**10**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**12**	10. Consultations	**5**
4. Research in library	**6**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**6**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**6**	13. Other activities…	**0**
7. Preparation for quizzes	**6**	14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90		

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between arithmetic, algebraic and topological properties of valued fields. 2. Knowledge and understanding connections between local and global aspects of Algebra and Number Theory. 3.
	2. Instrumental 1. Ability to use the methods of valuation theory inpure and applied mathematics.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the valuation theory in contemporary mathematics.

SYLLABUS	**Lecture** *:* 1. Valuations and absolute values on fields. 2. Algebraic and topological properties of valued fields. 3. Complete fields. Hensel Lemma and its consequences. 4. Prolongations of valuations and ramification theory. 5. The field of Newton-Puiseux series. 6. Local fields and their classification. 7. Division algebras over local fields. **Tutorials :** 1. P-adic numbers. 2. Local-global principle in Number Theory. 3. P-adic analogue of the complex number field **C**. 4. Elements of p-adic analysis. 5. Irreducible polynomials over local fields. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 10 lectures/tutorials.

	1. Z.I. Borevitch, I.R. Shafarevitch, Number Theory 2. .E. Artin, Algebraic Bunbers and Algebraic Functions. 3. I. Reiner, Maximal orders, Academic Press 1975.

Bibliography	4. F. Q. Gouvea p-adic Numbers-an Introduction, Springer 1997. 5. J.P.Serre, Local Fields, Springer 1979. 6. M. Vajaitu, A. Zaharescu Non-archimedean Integration and Applications, Romanian Academic Press 2007.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**70%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**10%**
- results to mid-term examination (oral, optional)	**0%**
- scientific reports, symposium etc	**20%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic tests/quizzes/homeworks**	**Correct solutions to all subjects in final exam.** **Successful presentations of scientific reports.** **Good results to all periodic tests/quizzes/homeworks**

Op.A45 Multiplicative Ideal Theory

Name	**Multiplicative Ideal Theory**			Code	**O.A.45**	
Year of study	II	Semester	2	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities						DS
Type{Ob – compulsory, Op- elective, F – optional}				F	ECTS	**5**
Total hours in curriculum	**30**	Total hours for individual study		**90**	Total hours per semester	**120**
Teacher(s)	Assoc. Prof. Tiberiu Dumitrescu					

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Algebra I, II.
	Recommended	Commutative Algebra, Algebraic Number Theory.

Estimated time (hours per semester) for the required individual study				
1. Learning by using one's own course notes	**14**		8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**14**		9. Preparation for exam	**14**
3. Study of indicated bibliography	**12**		10. Consultations	**7**
4. Research in library	**12**		11. Field research	**0**
5. Specific preparation for practicals/tutorials	**0**		12. Internet research	**7**
6. Preparation of reports, small projects, homework	**7**		13. Other activities…	**0**

7. Preparation for quizzes	**0**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of basic techniques of Multiplicative Ideal Theory. 2. Knowledge and understanding of classes of examples. 3. Understanding connections with Number Theory and Algebraic Geometry.
	2. Instrumental 1. Ability to use the star operation machinery as a unifying tool for the whole theory. 2. Ability to compute class groups and to use them in solving specific problems (e.g. factorization problems).
	3. Attitudinal 1. to start reading recent papers in this area. 2. to begin doing research in this area. 3. to interact with the Multiplicative Ideal Theory community.

SYLLABUS	**Lecture** *:* 1. Star operations on integral domains. 2. Abstract elementary number theory. 3. Fractional divisorial ideals. 4. Invertible ideals and class groups. 5. Valuation, Prufer and Bezout domains. 6. Krull domains and generalizations. 7. Almost Dedekind domains. **Tutorials :** 1. Applications and illustrations. 2. Solving homework exercises. 3. Student short papers presentations.

Bibliography	1. R. Gilmer, Multiplicative ideal theory (Queen's Papers în Pure and Applied Mathematics 90), Kingston, 1992. 2. F. Halter-Koch, Ideal systems: An introduction to multiplicative ideal theory (Monographs and Textbooks în Pure and Applied Mathematics 211), Dekker, 1998. 3. C. Huneke and I. Swanson, Integral Closure of Ideals, Rings, and Modules (London Mathematical Society Lecture Note Series 336),

	Cambridge University Press 2006. 4. M. Fontana, J. Huckaba and I. Papick, Prufer domains, Dekker 1998. 5. M. Fontana, S. Kabbaj, B. Olberding and I. Swanson (Editors), Commutative Algebra, Noetherian and Non-Noetherian Perspectives, Springer, 2010.
Necessary scientific infrastructure	Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**80.00%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**10%**
- results to mid-term examination (oral, optional)	**0.00%**
- scientific reports, symposium etc	**10%**
- other activities (to be specified) …………………	**0%**

Final evaluation methods, E/V.

Written exam

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results at homeworks.**	**Correct solutions to all subjects in final exam.** **Good results at homeworks or successful presentations of scientific reports.**

Op.G41 Vector Bundles and Applications

Name	**Vector Bundles and Applications**		Code	**Op.G41**		
Year of study	II	Semester	2	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS	**5**
Total hours in curriculum	**30**	Total hours for individual study		**90**	Total hours per semester	**120**
Teacher(s)	Assoc. Prof. Victor Vuletescu					

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Differential Geometry on Manifolds; Sheaf Theory;
	Recommended	Complex analysis; Algebraic Topology

Estimated time (hours per semester) for the required individual study				
1. Learning by using one’s own course notes	**10**		8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**10**		9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**		10. Consultations	**5**
4. Research in library	**6**		11. Field research	**0**
5. Specific preparation for practicals/tutorials	**10**		12. Internet research	**8**

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (semester) = 90			

<table>
<tr><td colspan="2">General competences (mentioned in MSc program sheet)</td></tr>
<tr><td rowspan="3">Specific competences</td><td>1. Knowledge and understanding

2. Knowledge and understanding of the interplay between geometry and topology.
3. Understanding the importance of the study of vector bundles on geometric properties.
4. Ability to use topological and differential tools in geometry problems.</td></tr>
<tr><td>2. Instrumental

1. Ability to use mathematical methods studied in various previous courses for solving specific geometric problems.
2. Ability to decide classification problems in geometry by using complex analytic tools.</td></tr>
<tr><td>3. Attitudinal

1. to develop an interest for the field;
2. to realize the importance of the field of complex geometry in contemporary mathematics
3. to assume an ethical conduct in scientific research;
4. to optimally valorise one’s own potential in scientific activities.</td></tr>
</table>

<table>
<tr><td>SYLLABUS</td><td>Lecture :

1. Basic definitions, examples; the tautological bundle on projective spaces and on grassmanians.
2. Operations with vector bundles.
3. The projectivisation of a vector bundle: splitting manifolds.
4. Classification of line bundles (real and complex).
5. Characteristic classes (Chern and Stiefel-Whitney) defined topologically
6. Chern classes defined using differential forms.
7. Classifying spaces for vector bundles.
8. Applications of characteristic classes: obstructions to embeddings, vector fields on spheres.
9. Positive line bundles on complex manifolds.
Tutorials :</td></tr>
</table>

	1. Examples of vector bundles; tangent bundle, tensor bundles, etc. 2. Examples of non-trivial vector bundles. 3. Computation of Chern and Stiefel-Whitney classes of the tangent bundle for some explicit manifolds. 4. Examples of applications of characteristic classes **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.
Bibliography	1. R. Bott, L. Tu; *Differential forms în algebraic topology*. Graduate Texts în Mathematics, 82. Springer-Verlag, New York-Berlin, 1982 2. R.O. Wells, Differential analysis on complex manifolds. Third edition. With a new appendix by Oscar Garcia-Prada. Graduate Texts in Mathematics, 65. *Springer, New York,* 2008. 3. R. Lazarsfeld; *Positivity în algebraic geometry*. II. *Positivity for vector bundles, and multiplier ideals*. Ergebnisse der Mathematik und ihrer Grenzgebiete. 3. Folge. A Series of Modern Surveys în Mathematics 49. Springer-Verlag, Berlin, 2004 4. Ch. Okonek, M. Schneider, H. Spindler Vector bundles on complex projective spaces. Corrected reprint of the 1988 edition. With an appendix by S. I. Gelfand. Modern Birkhäuser Classics. *Birkhäuser/Springer Basel AG, Basel,* 2011
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam	**Correct solutions to all subjects in final exam. Correct solutions to homework problems.**

Average results to periodic/continuous testing.	**Successful presentations of scientific reports. Good results to periodic/continuous testing.**

Op.G42 Algebraic Groups

Name	**Algebraic Groups**			Code	**Op.G42**		
Year of study	II	Semester	2	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**30**	Total hours for individual study		**90**	Total hours per semester		**120**
Teacher(s)	Prof. Marian Aprodu, Assoc. Prof. Cristian Voica						

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**					
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**	Total	C	S	L	P	
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**10**			

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Algebraic geometry: Sheaf theory; Commutative algebra;
	Recommended	Differential Geometry on Manifolds; Algebraic Topology; Lie groups

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**10**	8. Preparation of presentations.	**5**
2. Learning by using manuals, lecture notes	**10**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**6**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**10**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**5**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between algebra, geometry and topology. 2. Understanding the influence of algebraic context on geometric properties. 3. Ability to use complex algebraic tools in geometry problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific geometric problems. 2. Ability to decide classification problems in geometry by using complex analytic tools.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the field of complex geometry in contemporary mathematics 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Introduction. Algebraic varieties, definitions, examples. Projective algebraic varieties. The homogenous coordinates ring. 2. Affine groups; definitions, examples. Actions of algebraic groups on varieties. 3. Semidirect products, linearization of affine groups. 4. The Lie algebra associated to an algebraic group. 5. Representations, the adjoint representation. Reductive linear groups, examples. 6. Elements of the theory of invariants: Hilbert's theorem of finiteness of invariants. 7. Hilbert series of algebraic groups. 8. Classical invariant theory, the Cayley-Sylvester formula. **Tutorials :** 1. Examples of algebraic varieties (affine and projective). Computations of homogeneous coordinate rings. 2. Explicit examples of affine groups and actions. 3. Computations of Lie algebras. 4. Examples and constructions of reductive groups.

	5. Applications of Hilbert's finiteness theorem. 6. Computations of Hilbert series. 7. Applications of the Cayley-Sylvester formula. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. S. Mukai; *An introduction to invariants and moduli,* Cambridge Studies în Advanced Mathematics 81 (2012). 2. D. Mumford; *Abelian varieties,* Tata Institute Bombay, Hindustan Book Agency, New Delhi, 2008. 3. D. Mumford, J. Fogarty, J. Kirwan; *Geometric invariant theory*. Third edition. *Springer-Verlag, Berlin,*1994. 4. J. Humphreys; *Linear algebraic Groups,* Graduate Texts în Math. 21, Springer-Verlag, 1980
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.G43 Relativity Theory

Name	Relativity Theory		Code	**Op.G43**	
Year of study	II	Semester 2	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities					DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS	**5**
Total hours in curriculum	**30**	Total hours for individual study	**90**	Total hours per semester	**120**
Teacher	Prof. Gabriel Pripoae				

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Differential Geometry on Manifolds, Real and Complex analysis
	Recommended	Differential (ordinary and partial) equations.

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**6**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**20**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**10**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between analysis, geometry and topology in the study of relativity. 2. Understanding the interpretation of various relativistic phenomena.
	2. Instrumental 1. Ability to use geometrical methods and tools studied in various previous courses for solving specific relativity problems. 2. Ability to describe phenomena in relativity using mathematical models.
	3. Attitudinal 1. To develop an interest for the field. 2. To realize the importance of the field of relativity. 3. To assume an ethical conduct in scientific research. 4. To optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Semi-Riemannian manifolds. Levi-Civita connections. Geodezics. Curvature. Ricci curvature. Einstein manifolds. 2. Harmonic maps on semi-Riemannian manifolds. 3. Semi-Riemannian space forms. 4. Lorentz manifolds. Causality. Temporal orientation. 5. Special relativity. Minkowski spacetime. Particles, observables. Relativistic effects. Energy-momentum tensor. 6. The principles of general relativity. Einstein equations. Cosmological models (Robertson-Walker, Einstein-de Sitter, Friedmann). The Big-Bang theory. 7. The geometry of black-holes. **Tutorials :** 1. Examples of semi-Riemannian manifolds. 2. Construction of harmonic maps between semi-Riemannian manifolds. 3. Interpretation of relativistic phenomena. 4. Concrete computations (using geometric tools) in relativity. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 10 lectures/tutorials.

Bibliography	1. A. Besse, *Einstein spaces*, Springer, 2008. 2. J. Natario, *General Relativity without Calculus*, Springer, 2011. 3. B. O'Neill, *Semi-Riemannian geometry*, Academic Press, 1983. 4. L. Ryder, *Introduction to general relativity*, Cambridge Univ. Press, 2009. 5. B. Schutz, *A First Course în General Relativity*, Cambridge Univ. Press, 2009.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.G44 Variational Methods in Riemannian Geometry

Name	Variational Methods in Riemannian Geometry		Code	**Op.G44**		
Year of study	II	Semester	2	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS		**5**
Total hours in curriculum	**30**	Total hours for individual study	**90**	Total hours per semester		**120**
Teacher	Assoc. Prof. Catalin Gherghe					

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Differential Geometry on Manifolds, Real and Complex analysis
	Recommended	Differential (ordinary and partial) equations.

Estimated time (hours per semester) for the required individual study				
1. Learning by using one’s own course notes	**8**		8. Preparation of presentations.	**6**
2. Learning by using manuals, lecture notes	**8**		9. Preparation for exam	**20**
3. Study of indicated bibliography	**10**		10. Consultations	**5**
4. Research in library	**5**		11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**		12. Internet research	**8**

6. Preparation of reports, small projects, homework	**10**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

<table>
<tr><td colspan="2">General competences (mentioned in MSc program sheet)</td></tr>
<tr><td rowspan="3">Specific competences</td><td>1.Knowledge and understanding
1. Knowledge and understanding of the interplay between analysis, geometry and topology.
2. Understanding the meaning of geodesic, minimal submanifold, harmonic map.
3. Ability to use complex analytic tools in geometry problems.</td></tr>
<tr><td>2. Instrumental
1. Ability to use mathematical methods and tools studied in various previous courses for solving specific geometrical problems.
2. Ability to describe and solve problems in geometry by using tools from complex analysis.</td></tr>
<tr><td>3. Attitudinal
1. To develop an interest for the field.
2. To realize the importance of geometric variational theory in contemporary mathematics.
3. To assume an ethical conduct in scientific research.
4. To optimally valorise one’s own potential in scientific activities.</td></tr>
</table>

<table>
<tr><td>SYLLABUS</td><td>Lecture :
1. The Euler-Lagrange equations in the Euclidian space.
2. Geodesics on surfaces. The first variation of the arc length. Bonnet theorem.
3. Jacobi fields. Conjugate points.
4. Minimal surfaces. Variational methods.
5. Area minimizers surfaces. Second variation formula.
6. Harmonnic maps between Riemannian manifolds. The first variation formula.
7. The stability of harmonic maps. The second variation formula.
8. Holomorphic maps between complex manifolds
Tutorials :
1. Explicit computations of the solutions of the Euler-Lagrange equations. Geodesics.
2. Examples of minimal surfaces.
3. Examples of harmonic maps.
4. Construction of harmonic maps

N.B. The above is a description of the topics to be covered and are not in</td></tr>
</table>

	1-1 correspondence with the 10 lectures/tutorials.

Bibliography	1. T. Colding, W.Minicozzi, *A Course in Minimal Surfaces* – AMS 2011. 2. John Oprea, *Differential Geometry and its Applications*, Math. Assoc. of America, 2007. 3. Hajime Urakawa, *Calculus of Variations and Harmonic Maps*, AMS, 1991. 4. Jurgen Jost, *Riemannian Geometry and Geometry Analysis,* Springer, 2005.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.G45 Kaehler Manifolds

Name	**Kaehler Manifolds**			Code	**Op.G45**	
Year of study	II	Semester	2	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS	**5**
Total hours in curriculum	**30**	Total hours for individual study		**90**	Total hours per semester	**120**
Teacher(s)	Prof. Liviu Ornea, Assoc. Prof. Victor Vuletescu					

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Riemannian geometry; Complex analysis
	Recommended	Algebraic Geometry; Algebraic Topology; Differential Topology

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**10**	8. Preparation of presentations.	**3**
2. Learning by using manuals, lecture notes	**10**	9. Preparation for exam	**16**
3. Study of indicated bibliography	**15**	10. Consultations	**5**
4. Research in library	**8**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**
6. Preparation of reports, small projects, homework	**5**	13. Other activities…	**0**

7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between algebraic and Riemannian geometry 2. Ability to use complex analytic tools in Riemannian geometry problems.
	2. Instrumental 1. Ability to use mathematical methods studied in various previous courses for solving specific geometric problems. 2. Ability to decide classification problems in Riemannian geometry by using complex analytic tools. 3. Ability to attack more advanced and sophisticated problems in algebraic and Riemannian geometry.
	3. Attitudinal 1. to develop an interest for the field; 2. to realize the importance of the fields of algebraic and Riemannian geometry in contemporary mathematics and in theoretical physics; 3. to assume an ethical conduct in scientific research; 4. to optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Complex and Hermitian manifolds. Canonical connexion. 2. Kaehler manifolds. Curvature. 3. Hodge theory. Topological consequences. 4. Chern classes. Calabi-Yau theorem. 5. Kaehler-Einstein manifolds. 6. Kodaira embedding theorem. 7. Vanishing theorems. 8. Bundles. Divisors. Adjunction formula. **Tutorials :** 1. Examples and constructions of Kaehler manifolds. 2. Curvature of projective spaces. 3. Blow-up. Examples. 4. Weitzenboeck formula. 5. Quaternion and hyperkaehler manifolds.

	N.B. The above is a description of the topics to be covered and are not in 1-1 correspondence with the 14 lectures/tutorials.

Bibliography	1. W. Ballmann, *Lectures on Kähler manifolds*, European Math. Soc., 2006. 2. J.-P. Demailly, *Complex analytic and differential geometry*, disponibilă online la adresa http://www-fourier.ujf-grenoble.fr/~demailly/manuscripts/agbook.pdf 3. D. Huybrechts, *Complex geometry. An introduction*, Springer, 2005. 4. A. Moroianu, *Lectures on Kähler geometry*, Cambridge Univ. Press, 2007 5. C. Voisin, *Hodge theory and complex algebraic geometry, I*, Cambridge Univ. Press, 2002.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities (to be specified) …………………	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.C41 Applied Cryptography

Name	Applied Cryptography			Code	**Op.C41**		
Year of study	II	Semester	2	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU-humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**30**	Total hours for individual study		**90**	Total hours per semester		**120**
Teacher	Dumitru Stamate						

Faculty	**Mathematics and Computer Science**	**Total hours per semester in curriculum**				
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Computational cryptography
	Recommended	Number theory

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**6**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**20**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**
6. Preparation of reports, small projects, homework	**10**	13. Other activities…	**0**

7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the general digital signatures, ECommerce general protocols, E-voting protocols. 2. Understanding the importance of Email privacy.
	2. Instrumental 1. Ability to use tools studied in the previous cryptography courses for the design of digital signature 2. Ability to work with ECommerce and E-voting protocols.
	3. Attitudinal 1. To develop an interest for the field. 5. To realize the importance of applied cryptography in real life. 6. To assume an ethical conduct in scientific research. 7. To optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Digital signatures. General signature schemes. Electronic signature standards. Undeniable signature protocols. Proxy signature schemes. Fail-Stop signatures. 2. Elements of ECommerce. ECommerce architecture. Electronic Payment Systems. Challenge-response systems. Electronic payment systems. Digital Cash protocol. Electronic wallets. Secure Electronic Transaction (SET - protocol). Smart cards. 3. E-voting. Secret sharing scheme type protocols. Challenge-response systems type protocol. E-voting security. 4. Email privacy. **Tutorials :** 1. Explicit examples of digital signatures schemes. 2. Training implementation of ECommerce protocols. 3. Explicit construction of E-voting schemes. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 10 lectures/tutorials.

	1. A. Bruen, M. Forcinito, *Cryptography: Information Theory, and Error - Correction,* Wiley Interscience, 2005.

Bibliography	2. A. Konheim, *Computer Security and Cryptography*, Wiley Interscience, 2007. 3. A. Menezes, P.Oorschot, S. Vanstome, *Handbook of Applied Cryptography,* CRC Press, 2001 4. D. Salmon, *Data Privacy and Security*, Springer Professional Computing, 2003 5. B. Schneier, *Applied Cryptography*, John Wiley and Sons, 1996 6. B. Schneier, *Schneier's Cryptography Classics Library: Applied Cryptography, Secrets and Lies, and Practical Cryptography*, Wiley, John & Sons, 2007
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.C42 Information Flow Security

Name	Information Flow Security			Code	**Op.C42**	
Year of study	II	Semester	2	Assessment (E/V/C)		E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities						DF
Type{Ob – compulsory, Op- elective, F – optional}			Op	ECTS		**5**
Total hours in curriculum	**30**	Total hours for individual study	**90**	Total hours per semester		**120**
Teacher	Adrian Atanasiu					

		Total hours per semester in curriculum				
Faculty	**Mathematics and Computer Science**					
Department	**Mathematics**					
Main domain (sciences, art, culture)	**Exact Sciences**					
Domain of master program	**Mathematics**	Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**	**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Computational cryptography
	Recommended	Number theory

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**6**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**20**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**

6. Preparation of reports, small projects, homework	**10**		13. Other activities…	**0**
7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of security protocols and Secret sharing schemes. 2. Understanding the importance of the keys management..
	2. Instrumental 1. Ability to use tools studied in the previous cryptography courses for designing security protocols and keys management. 2. Ability to work with pseudo-random number generators.
	3. Attitudinal 1. To develop an interest for the field. 2. To realize the importance of the secure information flow in real life. 3. To assume an ethical conduct in scientific research. 4. To optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Verification of security protocols. (General security properties. Model checking security pattern compositions. Abadi-Rogaway model.) 2. Secret sharing schemes. (Access structures and general models. Share schemes. Visual cryptography) 3. Session keys management (General properties. Classifications. Standard models. Needham-Schroeder protocol. Kerberos protocol. Diffie –Hellmann problem based protocols) 4. Pseudo-random number generators (Cryptographic pseudorandom data generators. Generations using LFSR. Testing pseudo-random numbers generators) **Tutorials :** 1. Explicit examples of secret sharing schemes. 2. Explicit examples using Needham-Schroeder protocol and Kerberos protocol. 3. Implementations of pseudo-random number generators. **N.B.** The above is a description of the topics to be covered and are not in

	1-1 correspondence with the 10 lectures/tutorials.
Bibliography	1. H.F. Tipton, M. Krause, *Information Security Management Handbook*, Aurebach Publications, 2004. 2. A. Konheim, *Computer Security and Cryptography,* Wiley Interscience, 2007. 3. D. Salmon: Data Privacy and Security, Springer Professional Computing, 2003. 4. A. Cremers**,** S. Mauw**,** *Operational Semantics and Verification of Security Protocols, Springer*, 2012.
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**

Op.C43 Theory of Codes

Name	Theory of Codes			Code	**Op.C43**		
Year of study	II	Semester	2	Assessment (E/V/C)			E
Formative category: DF – fundamental, DG – general, DS – special, DE – economics/managerial, DU- humanities							DF
Type{Ob – compulsory, Op- elective, F – optional}				Op	ECTS		**5**
Total hours in curriculum	**30**	Total hours for individual study		**90**	Total hours per semester		**120**
Teacher	Assoc. Prof. Catalin Gherghe						

Faculty	**Mathematics and Computer Science**		**Total hours per semester in curriculum**				
Department	**Mathematics**						
Main domain (sciences, art, culture)	**Exact Sciences**						
Domain of master program	**Mathematics**		Total	C	S	L	P
Program name	**Algebra, Geometry and Cryptography**		**30**	**20**	**10**		

** C-lecture, S-practicals/tutorials, L-laboratory practical activity, P-scientific project

Prerequisites	Required	Linear Algebra, Algebra1, Algebra 2
	Recommended	Projective geometry

Estimated time (hours per semester) for the required individual study			
1. Learning by using one's own course notes	**8**	8. Preparation of presentations.	**6**
2. Learning by using manuals, lecture notes	**8**	9. Preparation for exam	**20**
3. Study of indicated bibliography	**10**	10. Consultations	**5**
4. Research in library	**5**	11. Field research	**0**
5. Specific preparation for practicals/tutorials	**5**	12. Internet research	**8**
6. Preparation of reports, small projects, homework	**10**	13. Other activities…	**0**

7. Preparation for quizzes	**5**		14. Other activities….	**0**
	TOTAL hours of individual study (/semester) = 90			

General competences (mentioned in MSc program sheet)	
Specific competences	**1.Knowledge and understanding** 1. Knowledge and understanding of the interplay between linear algebra, discrete geometry and algebraic geometry in codes theory. 2. Understanding how error correcting codes work in real life.
	2. Instrumental 1. Ability to use tools studied in various previous courses (i.e. linear algebra, geometry, algebraic geometry, algebraic curves) for describing several codes. 2. Ability to encode, decode and correct errors using algebra and linear algebra.
	3. Attitudinal 1. To develop an interest for the field. 2. To realize the importance of codes theory (as a field of mathematics) in real life. 3. To assume an ethical conduct in scientific research. 4. To optimally valorise one's own potential in scientific activities.

SYLLABUS	**Lecture** *:* 1. Information theory. Entropy. Huffman encoding. 2. Error detecting and error correcting codes. Hamming distance. The minimum distance of a block code. 3. Linear codes. Generator and check matrix. Encoding and decoding with linear codes. The syndrome decoding. 4. Bounds on codes theory. Gilbert-Varshamov, Hamming, Singleton, Plotkin. Perfect codes. 5. Hamming codes. 6. Reed –Muller codes. 7. Cyclic codes. 8. BCH codes. 9. Reed-Solomon codes. 10. Quadratic residue codes. 11. Goppa codes 12. Algebraic geometric codes. **Tutorials :**

	1. Solving elementary problems using codes theory. 2. Explicit correction of errors using Hamming, Reed-Muller, cyclic codes. 3. Encoding and decoding using Hamming, Reed-Muller, cyclic codes. 4. Explicit construction of codes using algebraic curves. **N.B.** The above is a description of the topics to be covered and are not in 1-1 correspondence with the 10 lectures/tutorials.

Bibliography	1. W. C. Huffman, V. Pless, *Fundamentals of Error-Correcting Codes*, Cambridge Press, 2010. 2. S.Ling, C.Xing, *Coding Theory*, Cambridge University Press 2004. 3. Judy L. Walker, *Codes and Curves*, Student Mathematical Library, AMS, 2000 4. C.Huffman, *Fundamental of Error Correcting Codes*, Cambridge University Press, 2010
Necessary scientific infrastructure	- Library

Final mark is given by:	Weight, in % {Total=100%}
- final exam results	**60%**
- hands-on lab test&quiz	**0%**
- results to periodic tests/quizzes/homeworks	**20%**
- results to mid-term examination (oral, optional)	**20%**
- scientific reports, symposium etc	**0%**
- other activities	**0%**
Final evaluation methods, E/V. **Written exam**	

Minimal requirements for mark 5 (10 point scale)	Requirements for mark 10 (10 point scale)
Correct solutions to indicated subjects (for mark 5) in final exam **Average results to periodic/continuous testing.**	**Correct solutions to all subjects in final exam.** **Correct solutions to homework problems.** **Successful presentations of scientific reports.** **Good results to periodic/continuous testing.**
