Master's Program in Applied Mathematics

Department of Mathematics

Semester 1

Teaching Unit	Subject	Credit	Coefficient	Lecture	Tutorial	Lab	Continuous Assessement	Final Exam
Fundamental unit credit=12 coefficient=6	Complementary Topics in Probability Theory	6	3	3h	1h30	x	33%	67%
	Complementary Topics on Integration and Lebesgue Spaces	6	3	3h	1h30	x	33%	67%
Fundamental unit credit=6 coefficient=3	Functional analysis 1 (Required subject)	6	3	3h	1h30	x	33%	67%
Methodological unit credit=9 coefficient=5	Optimization	5	3	1h30	1h30	x	33%	67%
	Numerical methods 1	4	2	1h30	1h30	1h30	40%	60%
Discovery unit credit=2 coefficient=1	Research methodology	2	1	1h30	x	x	x	100%
Transversal unit credit=1 coefficient=1	Corruption and deontology	1	1	1h30	x	x	x	100%

Semester 2

Teaching Unit	Subject	Credit	Coefficient	Lecture	Tutorial	Lab	Continuous Assessement	Final Exam
Fundamental unit credit=12 coefficient=6	Fourier analysis	6	3	3h	1h30	x	33%	67%
	Distributions 1	6	3	3h	1h30	x	33%	67%
Fundamental unit credit =6 coefficient=4	Functional analysis 2 (Required subject)	6	4	3h	1h30	x	33%	67%
Methodological unit credit=5 coefficient=2	Numerical methods 2	5	2	1h30	1h30	1h30	40%	60%
Methodological unit credit=4 coefficient=2	Differential Equations in Banach Spaces - Calculus of Variations	4	2	1h30	1h30	x	33%	67%
Discovery unit credit=2 coefficient=1	Computer Science (Software)	2	1	1h30	x	1h30	33%	67%
Transversal unit credit=1 coefficient=1	English 1	1	1	1h30	x	x	x	100%

Semester 3

Teaching Unit	Subject	Credit	Coefficient	Lecture	Tutorial	Lab	Continuous Assessement	Final Exam
Fundamental unit credit=12 coefficient=6	Spectral Theory of Operators	6	3	3h	1h30	x	33%	67%
	Elliptic Variational Problems	6	3	3h	1h30	x	33%	67%
Fundamental unit credit=6 coefficient=3	Distributions 2	6	3	3h	1h30	x	33%	67%
Methodological unit credit=9 coefficient=5	Semi groups and Applications to PDE	5	3	3h	1h30	x	33%	67%
	Approximation Theory	4	2	1h30	1h30	1h30	40%	60%
Discovery unit credit=2 coefficient=1	Seminars	2	1	1h30	x	x	100%	x
Transversal unit credit=1 coefficient=1	English 2	1	1	1h30	x	x	x	100%

1st Year Master's in Mathematics: Applied Mathematics

Semester 1

Fundamental unit (UEF)

Core Unit (UEF1)

- **Course:** Complementary Topics in Probability Theory
    - **Credits:** 3
    - **Coefficient:** 6
    - **Objectives:** Enhance students' knowledge in probability theory.
    - **Prerequisites:** Basic understanding of probability and measure theory from undergraduate studies.
    - **Content:**
        1. Random Vectors:
            - Probability laws of random vectors.
            - Covariance matrix.
            - Inequalities involving random variables (e.g., Bienayme-Chebyshev, Markov).
            - Independence of random variables.
            - Gaussian random vectors.
            - Conditional expectation.
        2. Convergence of Random Variable Sequences:
            - Convergence in distribution.
            - Almost sure convergence.
            - Convergence in probability.
            - Convergence in p-th order mean.
        3. Characteristic and Generating Functions:
            - Characteristics of sums of independent random variables.
            - Inversion formula.
            - Moments and generating functions.
    - **Assessment:** Continuous work (33%), Final Exam (67%).
    - **References:**
        - G. Reischer et al., "Théorie des Probabilités: Problèmes et Solutions," Presses Université du Québec, 2002.
        - Jacod & Protter, "L'essentiel en Théorie des Probabilités," 2002.

Semester 1

Core Unit (UEF1)

- **Course:** Complementary Topics on Integration and Lebesgue Spaces

- **Credits:** 3
- **Coefficient:** 6
- **Objectives:** Advance understanding of integration theory.
- **Prerequisites:** Measure and integration theory from undergraduate studies.
- **Content:**

  1. Lebesgue Integration on $\mathbb{R}^n$:
     - Recap and extensions of Lebesgue integration on $\mathbb{R}$.
     - Product measure.
     - Fubini and Tonelli theorems.
     - Lebesgue measure on Borel sets in $\mathbb{R}^n$.
     - Convolution.
     - Convergence theorems.
  2. Lp Spaces ($\Omega \subset \mathbb{R}^n$):
     - Hilbertian analysis and L2(Ω) space.
     - Duality between Lp spaces.
     - Topology of Lp spaces: density, separability, compactness.
  3. Fourier Transform:
     - Fourier transform in L1(Ω).
     - Fourier transform in L2(Ω).
- **Assessment:** Continuous work (33%), Final Exam (67%).
- **References:**
  - G. Reischer et al., "Théorie des Probabilités: Problèmes et Solutions," 2002.
  - J. Jacod & P. Protter, "L'essentiel en Théorie des Probabilités," 2002.

Semester 1

Core Unit (UEF2)

- **Course:** Functional Analysis 1
  - **Credits:** 3
  - **Coefficient:** 6
  - **Objectives:** Deepen knowledge in functional analysis.
  - **Prerequisites:** Topology from undergraduate studies.
  - **Content:**

    1. Continuity and Convergence in Metric Spaces.
    2. Functional Spaces:
       - Types of convergence (simple, absolute, uniform, compact).
       - Equicontinuity and the Ascoli-Arzelà Theorem.
       - Stone-Weierstrass Theorem.
    3. Banach Spaces:
       - Spaces of continuous functions C(Ω), spaces of differentiable functions Ck(Ω).
    4. Bounded Linear Operators in Banach Spaces:
       - Fundamental theorems (Banach-Steinhaus, open mapping, closed graph).
    5. Duality in Banach Spaces and the Hahn-Banach Theorem.

6. Weak Topologies.
7. Reflexive and Separable Spaces.

- **Assessment:** Continuous work (33%), Final Exam (67%).
- **References:**
  - V. Trénoguine, "Analyse Fonctionnelle," Editions MIR-Moscou, 1985.
  - A. Kolmogorov & S. Fomine, "Elements de la Théorie des Fonctions et de l'Analyse Fonctionnelle," Editions MIR-Moscou, 1973.

Semester 1

Methodological Unit (UEM)

Core Unit (UEM1)

- **Course:** Optimization
  - **Credits:** 5
  - **Coefficient:** 3
  - **Objectives:** Develop advanced knowledge in optimization problems.
  - **Prerequisites:** Undergraduate optimization coursework.
  - **Content:**
    1. Optimization and Convexity:
       - Definition of an optimization problem.
       - Examples from physics and geometry.
       - General theorems on existence and uniqueness of the minimum for convex functions.
       - Applications in finite and infinite dimensions.
    2. Optimization with Constraints:
       - Lagrange multipliers.
       - Saddle points and Lagrangian function.
       - Duality.
    3. Iterative Algorithms:
       - Gradient method.
       - Projected gradient.
       - Gauss-Seidel method.
       - Conjugate gradient method.
       - Uzawa's algorithm.
  - **Assessment:** Continuous work (33%), Final Exam (67%).
  - **References:**
    - G. Allaire, "Analyse Numérique et Optimisation," 2005.
    - J. Baptiste Hiriart-Urruty, "Optimisation et Analyse Convexe: Exercices Corrigés," EDP Sciences, 2009.

Semester 1

Core Unit (UEM1)

- **Course:** Numerical Methods 1

- **Credits:** 4
- **Coefficient:** 3
- **Objectives:** Develop expertise in numerical analysis.
- **Prerequisites:** Numerical analysis from undergraduate studies.
- **Content:**

    1. Approximation of Solutions to Linear Systems:
        - Norms and convergence promoters.
    2. Eigenvalues and Eigenvectors.
    3. Solving Nonlinear Systems:
        - Newton's method.
        - Accelerated Newton's method.
        - Von Mises method.
        - Optimization methods.
        - Gradient and steepest descent methods.
        - Conjugate gradient method.
- **Assessment:** Continuous work (33%), Final Exam (67%).
- **References:**
    - J. Baranger, "Analyse Numérique," Hermann.
    - C. Brézinski, "Introduction à la Pratique du Calcul Numérique," Dunod.
    - M. Sibony, "Analyse Numérique," Hermann.
    - M. Lakrib, "Cours d'Analyse Numérique," OPU.

Semester 1

Discovery Unit (UED)

Core Unit (UED1)

- **Course:** Research Methodology
    - **Credits:** 2
    - **Coefficient:** 1
    - **Objectives:** Learn to write theses, research topics, etc.
    - **Prerequisites:** None.
    - **Content:**
        1. Introduction.
        2. Understanding the Assigned Work.
        3. Choosing and Limiting the Topic.
        4. Conducting Literature Review.
        5. Analysing Documents.
        6. Writing the Work.
    - **Assessment:** Continuous work (33%), Final Exam (67%).
    - **References:**
        - C. Gosselin, "L'information et le Travail de Recherche," Educatechnologiques, Vol. 2, No. 1, Université Laval, Québec, 1995.

- Mediatix, "Initiation à la Recherche Documentaire sur l'Internet," Université Paris X.

Semester 1

Transversal Unit (UET)

Core Unit (UET1)

- **Course:** Corruption and Work deontology
  - **Credits:** 1
  - **Coefficient:** 1
  - **Objectives:** Raise awareness about corruption risks and encourage ethical practices.
  - **Prerequisites:** None.
  - **Content:**
    1. Concepts of Corruption:
       - Definition and religious perspectives.
    2. Types of Corruption:
       - Financial, administrative, moral, and political corruption.
    3. Manifestations of Administrative and Financial Corruption:
       - Nepotism, favoritism, extortion, fraud, public fund mismanagement, organizational violations.
    4. Causes of Corruption:
       - Theoretical causes (civilizational, political, structural, economic, etc.).
       - General causes (weak institutions, conflicts of interest, rapid profit-seeking).
  - **Assessment:** Continuous work (33%), Final Exam (67%).
  - **References:**

- موسى , صافي إمام 5041 (. ه 5891 / م .) **استراتيجية الإصلاح الإداري وإعادة التنظيم في نطاق الفكر والنظريات** (ط5
- الرياض : دار العلوم للطباعة والنشر.
- http://www.islameiat.com/doc/article.php?sid=276&mode=&order=0
- بحر , يوسف . **الفساد الإداري ومعالجته من منظور إسلامي**
- http://www.scc-online.net/thaqafa/th_1.htm
- حمودي , همام . **مصطلح الفساد في القرآن الكريم.**
- http://209.61.210.137/uofislam/behoth/behoth_quran/16/a1.htm
- الفقي , مصطفى .**الفساد الإداري والمالي بين السياسات والإجراءات**
- http://www.cipe-egypt.org/articles/art0900.htm
- محمود , مهيوب خضر . **من معالم المدرسة العمرية في مكافحة الفساد.**
- http://www.hetta.com/current/mahyoob23.htm

Semester 2

Fundamental unit (UEF)

Core Unit (UEF1)

- **Course:** Fourier Analysis
  - **Credits:** 6
  - **Coefficient:** 3
  - **Objectives:** Enhance understanding of Fourier methods in mathematical analysis.
  - **Prerequisites:** Mathematical physics equations and Fourier series from undergraduate studies.
  - **Content:**
    1. Boundary Value Problems:
       - Mathematical formulation of physical problems.
       - Partial differential equations.
       - Laplacian in various coordinate systems.
    2. Fourier Series:
       - Recap of Fourier series.
       - Extensions to multiple variables.
       - Applications to boundary value problems.
    3. Techniques and Applications:
       - Heat equation.
       - Hilbertian techniques and Sobolev spaces on the circle.
  - **Assessment:** Continuous work (33%), Final Exam (67%).
  - **References:**

    - G. P. Tolstov, "Fourier Series," Dover Publications.
    - W. E. Williams, "Partial Differential Equations," Clarendon Press, Oxford, 1980.

Semester 2

Fundamental unit (UEF)

Core Unit (UEF1)

- **Course:** Distributions 1
  - **Credits:** 6
  - **Coefficient:** 3
  - **Objectives:** Provide foundational knowledge in distribution theory.
  - **Prerequisites:** Analysis and algebra from undergraduate studies.
  - **Content:**

    1. Basics:
       - Spaces of test functions and distributions.
       - Elementary operations.
       - Differentiation of distributions.
       - Compactly supported distributions.

2. Applications:
    - Convolutions.
    - Tensor products.
- **Assessment:** Continuous work (33%), Final Exam (67%).
- **References:**
    - R. Dautray & J. L. Lions, "Analyse Mathématique et Calcul Numérique," Masson, 1988.
    - R. Gouyon, "Intégration et Distributions," Vuibert, 1967.

Semester 2

Fundamental unit (UEF)

Core Unit (UEF2)

- **Course:** Functional Analysis 2
    - **Credits:** 6
    - **Coefficient:** 3
    - **Objectives:** Deepen understanding of functional analysis principles.
    - **Prerequisites:** Analysis and algebra from undergraduate studies.
    - **Content:**

        1. Hilbert Spaces:
            - Projections and representation theorems.
            - Hilbert bases.
        2. Operators:
            - Closed and closable operators.
            - Adjoints, resolvents, and spectra.
    - **Assessment:** Continuous work (33%), Final Exam (67%).
    - **References:**
        - V. Trénoguine, "Analyse Fonctionnelle," MIR-Moscou, 1985.
        - A. E. Taylor, "Introduction to Functional Analysis," Wiley, 1957.

Semester 2

Methodological Unit (UEM)

Core Unit (UEM1)

- **Course:** Numerical Methods 2
    - **Credits:** 5
    - **Coefficient:** 2
    - **Objectives:** Deepen knowledge of numerical methods in differential equations.
    - **Prerequisites:** Numerical analysis from undergraduate studies.
    - **Content:**
        1. Numerical Methods in Ordinary and Partial Differential Equations:
            - General overview and one-step methods.

        - Multi-step methods.
        - Finite element methods.
        - Applications of finite element methods to two-dimensional problems for partial differential equations:
            - Existence and uniqueness of solutions.
            - Numerical studies.
            - Computational implementation.
    - **Assessment:** Continuous work (33%), Final Exam (67%).
    - **References:**

        - J. Baranger, "Analyse Numérique," Hermann.
        - C. Brézinski, "Introduction à la Pratique du Calcul Numérique," Dunod.
        - M. Sibony, "Analyse Numérique," Hermann.
        - M. Lakrib, "Cours d'Analyse Numérique," OPU.

Semester 2

Methodological Unit (UEM)

Core Unit (UEM1)

- **Course:** Differential Equations in Banach Spaces - Calculus of Variations
    - **Credits:** 4
    - **Coefficient:** 2
    - **Objectives:** Provide in-depth knowledge of differential equations and calculus of variations.
    - **Prerequisites:** Elementary differential equations, topology, measure, and integration.
    - **Content:**

        1. Differential Equations (Cauchy Problem):
            - Maximum solutions, global uniqueness.
            - Cauchy problem solutions under Lipschitz and continuity conditions.
        2. Flows of Differential Equations:
            - Inequalities verified by solutions.
            - Continuity and differentiability of flows.
            - Parametric dependence.
        3. Linear Differential Equations:
            - General properties and homogeneous equations.
            - Methods of constant variation and resolvent equation analysis.
            - Homogeneous autonomous linear equations in $\mathbb{R}$n.
        4. Calculus of Variations:
            - C1 curve spaces.
            - Lagrangian functional differentiation.
            - Euler equations.
            - Legendre transformations and Hamiltonian equations.
    - **Assessment:** Continuous work (33%), Final Exam (67%).
    - **References:**

- Constantin Carathéodory, "Calculus of Variations and Partial Differential Equations of the First Order," 1967.
- Henri Cartan, "Cours de Calcul Différentiel," Hermann, Paris, 1977.
- Léonard Todjihounde, "Calcul Différentiel: Cours et Exercices Corrigés," Cépaduès-Editions, 2004.

Semester 2

Discovery Unit (UED)

Core Unit (UED1)

- **Course:** Computer Science (Software)
  - **Credits:** 2
  - **Coefficient:** 1
  - **Objectives:** Familiarize students with essential software for mathematics.
  - **Prerequisites:** Basic computer science knowledge.
  - **Content:**
    1. LaTeX.
    2. Scientific Workplace.
    3. MATLAB.
    4. Programming in C and C++.
    5. SAS.
  - **Assessment:** Continuous work (33%), Final Exam (67%).
  - **References:**
  - Web sites, books, etc. …..

Semester 2

Transversal unit (UET)

Core unit (UET1)

- **Course:** English 1
  - **Credits:** 1
  - **Coefficient:** 1
  - **Objectives:** Develop technical English skills.
  - **Content:** Determined by the instructor.
  - **Assessment:** Continuous work (33%), Final Exam (67%).
  - **References:**
  - Web sites, books, etc. …..

2d Year Master's in Mathematics: Applied Mathematics

Semester 3

Fundamental unit (UEF)

Core Unit (UEF1)

- **Course:** Spectral Theory of Operators
    - **Credits:** 6
    - **Coefficient:** 3
    - **Objectives:** Equip students with knowledge in the spectral theory of operators.
    - **Prerequisites:** Functional Analysis 1, Functional Analysis 2, and Topology.
    - **Content:**
        1. Bounded Operators:
            - Definitions and examples.
            - Bounded linear operators.
            - Inverse operators.
            - Self-adjoint operators and orthogonal projection operators.
            - Spectrum of an operator, resolvent, spectral radius.
        2. Unbounded Operators:
            - Closed operators, adjoint operators.
            - Symmetric and self-adjoint operators.
            - Spectrum and resolvent set.
        3. Compact Operators or Compact Resolvent:
            - Compactness and weak convergence.
            - Spectral theory of compact self-adjoint operators.
            - Spectral decomposition of compact self-adjoint operators and compact resolvent.
            - Picard's theorem and its applications.
    - **Assessment:** Continuous work (33%), Final Exam (67%).
    - **References:**
        - Angus E. Taylor, "Introduction to Functional Analysis," Wiley International Edition, 1957.
        - D. Huet, "Décomposition Spectrale et Opérateurs," PUF, 1976.
        - V. Trénoguine, "Analyse Fonctionnelle," Mir-Moscou, 1985.

Semester 3

Fundamental unit (UEF)

Core Unit (UEF1)

- **Course:** Elliptic Variational Problems
    - **Credits:** 6
    - **Coefficient:** 3
    - **Objectives:** Provide students with knowledge on elliptic problems.
    - **Prerequisites:** Analysis courses from undergraduate and Master 1 levels.
    - **Content:**

1. Sobolev Spaces.
2. Abstract Variational Problems:
   - Lax-Milgram Theorem.
3. Examples of Second-Order Elliptic Problems:
   - Dirichlet problems.
   - Neumann problems.
   - Mixed problems.
4. Regularity of Weak Solutions.
5. Maximum Principle.
6. Elementary Spectral Theory of Elliptic Variational Problems.

- **Assessment:** Continuous work (33%), Final Exam (67%).
- **References:**
  - H. Brésis, "Analyse Fonctionnelle," Masson, Paris, 1986.
  - L. C. Evans, "Partial Differential Equations," AMS, Providence, 1988.
  - P. A. Raviart, J.-M. Thomas, "Analyse Numérique des Équations aux Dérivées Partielles," Masson.

Semester 3

Fundamental unit (UEF)

Core Unit (UEF2)

- **Course:** Distributions 2
  - **Credits:** 6
  - **Coefficient:** 3
  - **Objectives:** Extend knowledge in the theory of distributions.
  - **Prerequisites:** Distributions 1 and undergraduate-level analysis.
  - **Content:**
    1. Spaces of Tempered Distributions.
    2. Fourier Transforms of Distributions.
    3. Sobolev Spaces.
    4. Applications to Partial Differential Equations.
  - **Assessment:** Continuous work (33%), Final Exam (67%).
  - **References:**
    - Vo Khac Khoan, "Espaces Vectoriels Topologiques, Distributions, Équations aux Dérivées Partielles," Vol. 1 and 2.
    - R. Dautray, J.-L. Lions, "Analyse Mathématique et Calcul Numérique," Vol. 3: Transformation, Sobolev, Opérateurs, Masson, 1988.

Semester 3

Methodological Unit (UEM)

Core unit (UEM1)

- **Course:** Semi groups and Applications to Partial Differential Equations

- **Credits:** 5
- **Coefficient:** 3
- **Objectives:** Equip students with knowledge in semigroup theory and its applications.
- **Prerequisites:** Topology and functional analysis.
- **Content:**
  1. Basic Concepts:
     - Sobolev spaces of natural and fractional order.
     - Bounded linear operators, extensions to densely defined operators.
     - Spectral theory, strong continuity, Fréchet derivative.
  2. Semigroups:
     - Linear evolution problems with initial values.
     - Semigroups generated by linear operators.
  3. Abstract Cauchy Problems:
     - Homogeneous and non-homogeneous initial value problems.
     - Weak solutions, regularity, and asymptotic behavior.
  4. Applications to Partial Differential Equations:
     - Parabolic equations.
     - Wave equations.
     - Schrödinger equation.
- **Assessment:** Continuous work (33%), Final Exam (67%).
- **References:**
  - R. Adams, "Semigroups of Linear Operators and Applications."
  - R. Dautray, J.-L. Lions, "Analyse Mathématique et Calcul Numérique," Vol. 8: Evolution, Semigroups, Variational, Masson, 1988.

Semester 3

Methodological Unit (UEM)

Core unit (UEM1)

- **Course:** Approximation Theory
  - **Credits:** 4
  - **Coefficient:** 2
  - **Objectives:** Expand knowledge in approximation theory within specific spaces.
  - **Prerequisites:** Undergraduate and Master 1 level analysis courses.
  - **Content:**
    1. Approximations in Normed Spaces.
    2. Uniqueness of Best Approximation:
       - Strict convexity.
    3. Uniform Approximation:
       - Chebyshev polynomials.
    4. Approximation in Hilbert Spaces:
       - Orthogonal polynomials.
       - Least squares approximation.

- **Assessment:** Continuous work (33%), Final Exam (67%).
- **References:**
    - A. Quaternani, R. Sacco, F. Saleri, "Polynômes Orthogonaux en Théorie de l'Approximation," Springer Milan, 2007.

Semester 3

Discovery Unit (UED)

Core unit (UED1)

- **Course:** Seminars
    - **Credits:** 2
    - **Coefficient:** 1
    - **Objectives:** Attend and prepare presentations on functional analysis and mathematical modeling of partial differential equations.
    - **Prerequisites:** Bachelor's and Master 1 level mathematics courses.
    - **Content:**
        - Topics will focus on:
            - Functional analysis.
            - Classical linear partial differential equations (modeling).
    - **Assessment:** 100% Continuous work.
    - **References:**
    - Web sites, books, etc. …..

Semester 3

Transversal Unit (UET)

Core unit (UET1)

- **Course:** English 2
    - **Credits:** 1
    - **Coefficient:** 1
    - **Objectives:** Develop technical English skills.
    - **Content:** Determined by the instructor.
    - **Assessment:** Continuous work (33%), Final Exam (67%).
    - **References:**
    - Web sites, books, etc. …..
