Study in Applied and Interdisciplinary Mathematics at Ohio State

The Department of Mathematics offers a single doctorate, Doctor of Philosophy in Mathematics. Students who achieve this degree receive a thorough graduate education in core mathematics and also have the opportunity to pursue research in applied and interdisciplinary directions. The PhD application process is the same for all students, and applicants are encouraged to indicate their interest on the application. Details about individual research programs can be found on individual faculty members' websites. This page gives a summary of the research areas in applied mathematics in the department, a list of courses of particular interest to students planning to do research related to applications, and a list of faculty members who have indicated applied research interests.

The department also offers several specialized programs at the Masters level. Details of that program can be found under Masters of Mathematical Sciences. A number of the research areas listed below may also be accessible and of interest to MMS students.

Research Areas in Applied and Interdisciplinary Mathematics in the Mathematics Department at OSU

1. Applications of PDEs in biology
   - Free boundary problems in tumor growth and organ specific diseases (Friedman, Lam)
   - Free boundary systems in wound healing and biofilms (Friedman, Xue)
   - Multi-scale methods in cell structure and movement (Xue)
   - Reaction-diffusion systems in ecology, population genetics, disease dynamics, and evolutionary game theory (Lou, Lam)

2. Applications of PDEs in physics and mechanics
   - Applied PDEs, especially in fluid dynamics, the Schrodinger equation, and wave maps (O. Costin)
   - Asymptotics and exponential asymptotics (O. Costin)
   - Conservation laws (Keyfitz)
   - Free boundary problems (Friedman)
   - General relativity: catastrophic gravitational collapse, black hole physics (Gerlach)
   - Integrable equations, semiclassical limits (Kodama, Tian)
   - Integrable systems and solitons (Kodama)
   - Mathematical physics: quantum mechanics, general relativity, statistical mechanics, random matrices as used in models of statistical mechanics (O. Costin)
   - Navier-Stokes equation, asymptotic methods in fluid problems and in quantum mechanics (Tanveer)
   - Nonlinear wave models: shallow water, liquid crystal, plasma (Tiglay)
   - Special relativity: quantum radiation, laser-driven plasma dynamics (Gerlach)
   - Weakly dispersive PDE and integrable evolution equations (Tiglay)

3. <u>Applied algebraic topology</u>
   - Computational algebraic topology (Dey, Ogle)
   - Directed algebraic topology and applications to dynamics (Krishnan)
   - Metric geometry-topology-probability and applications to topological data analysis (Dey, Memoli)
   - Stochastic topology (Kahle)
   - General (Burghelea, Davis, Dey (CSE), Belkin (CSE), Yusu Wang (CSE))

4. <u>Applied dynamical systems</u>
   - Applied singularity theory (Golubitsky)
   - Bifurcation theory and symmetry breaking (Golubitsky)
   - Hamiltonian systems: global action-angle coordinates and their obstructions (Gerlach)
   - Infectious diseases (Tien)
   - Mathematical and computational neuroscience (Best, Terman, Golubitsky)
   - Network dynamics (Golubitsky, Best, Terman)

5. <u>Applied Logic</u>
   - Logic applied to continuous control theory and hybrid systems (Miller)

6. <u>Fluid dynamics</u>
   - Compressible and incompressible flow (Keyfitz, Tiglay)
   - Hele-Shaw, water waves, bubble dynamics, fluid turbulence (Tanveer)
   - Relativistic Fluid Dynamics (Gerlach)
   - Solitons in shallow water wave equations (Kodama)
   - General (O. Costin)

7. <u>Mathematical biology</u>
   - Animal behavior, evolutionary games (Hamilton)
   - Atherosclerosis, kidney fibrosis, lung and other organ specific diseases (Friedman)
   - Autoimmune diseases (Friedman)
   - Biochemical signaling pathways and structure of cells (Dawes)
   - Collective cell movement, intracellular transport, cell biology of the neuron (Xue)
   - Computational cell biology (Chou)
   - Ecology and Evolution (Lam)
   - Infectious diseases, dynamics of networks (Tien)
   - Mathematical neuroscience (Best, Terman)
   - Modeling (Golubitsky, Rempala)
   - Population genetics, ecology, disease dynamics (Lou)
   - Tumor growth, chronic wounds (Friedman, Xue)

8. Probability and applied stochastics
    - Actuarial and financial mathematics (Ban)
    - Percolation, interacting particles on graphs, lattices and trees, competition and cooperative collaboration, spread of diseases (Sivakoff)
    - Random dynamics in neuroscience and physiology (Best)
    - Random perturbations of non-normal matrices, fragmentation processes, stochastic geometry, stochastic analysis (Paquette)
    - Stochastic dynamical systems and large volume approximations of stochastic dynamics (Rempala)

9. Scientific computing
    - Higher order numerical methods for hyperbolic problems (Chou)
    - General (Hiary, Memoli, Overman, Xiu)

10. Stochastic computing and data science
    - Uncertainty quantification for complex systems (Xiu)
    - High performance algorithms for stochastic computations (Xiu)
    - Numerical methods for data sciences and big data (Xiu)

11. Theoretical Computer Science
    - Algorithmic graph theory, algorithms on graphs on surfaces (Sidiropoulos)
    - Computational geometry, approximation algorithms, metric embeddings and their applications in the design of algorithms (Sidiropoulos)

Courses offered in Applied Mathematics

- Linear Algebra (5101)
- Linear Mathematics in Infinite Dimensions (5102)
- Finite Element Method (5168)
- Introduction to Real Analysis, I, II (5201,5202)
- Introduction to Complex Analysis (5221)
- Complex Variables and Applications (5251)
- Applied Differential Equations I (ODE) (5401)
- Applied Differential Equations II (PDE) (5402)
- Calculus of Variations and Tensor Calculus (5451)
- Probability (5530,6251,6252)
- Essentials of numerical methods (5601)
- Computational PDE (5602)
- Numerical Linear Algebra (5603)
- Life Contingencies I, II (5630,5631)
- Financial Economics for Actuaries (5632)
- Loss Models I, II (5633,5634)
- Stochastic Calculus for Finance I, II (5635,5636)
- Mathematical modeling of biological processes (5651)
- Integrated molecular and cellular biology for non-biologists (5660)
- Mathematical methods in relativity I, II (5756,5757)
- Algorithmic Graph Theory (5800)
- ODE I,II,III (6411,7412,7413)
- PDE I,II,III (6451,7452,7453)
- Numerical Methods in Scientific Computing I, II (6601,6602)
- Computational PDE I,II (7611,7612)
- Applied complex variables and Asymptotics I, II (7651,7652)

The following courses are taught as topics courses

- Algorithm design under a geometric lens
- Asymptotics
- Dynamical systems
- Geometry in data analysis
- Hypergeometric functions and Painlevé equations
- Mathematical fluid dynamics
- Mathematical statistics
- Mathematics of infectious disease dynamics
- Modeling in evolutionary ecology
- Nonlinear waves
- Quantitative neuroscience

- Random graphs
- Random spaces and groups
- Stochastic epidemic models
- Topics in Sheaf Theory
- Topological and geometrical ideas in data analysis
- (CSE) Algorithm design under a geometric lens

Faculty Associated with Applied and Interdisciplinary Mathematics Research

Chunsheng Ban
Mikhail Belkin (Statistics and CSE)
Janet Best
Dan Burghelea (emeritus)
Ching-Shan Chou

Ovidiu Costin
Michael Davis
Adriana Dawes (60% Mathematics, 40% Molecular Genetics)
Tamal Dey (courtesy, appointment in CSE)
Avner Friedman (Distinguished University Professor)

Ulrich Gerlach (emeritus)
Martin Golubitsky (Distinguished Professor of Math and Physical Sciences)
Ian Hamilton (20% Mathematics, 80% EEOB)
Ghaith Hiary
Matthew Kahle

Barbara Lee Keyfitz (Charles Saltzer Professor)
Yuji Kodama
Sanjeevi Krishnan
Adrian Lam
Yuan Lou

Facundo Memoli
Chris Miller
Crichton Ogle
Edward Overman
Elliot Paquette

Grzegorz Rempala (courtesy, appointment in Public Health)
Anastasios Sidiropoulos (20% Mathematics, 80% CSE)
David Sivikoff (40% Mathematics, 60% Statistics)
Saleh Tanveer
David Terman

Fei-Ran Tian
Joseph Tien
Feride Tiglay
Yusu Wang (CSE)
Dongbin Xiu (Ohio Eminent Scholar)

Chuan Xue