APPLIED & COMPUTATIONAL MATHEMATICS (ACME)

A NEW DEGREE FOR 21ST CENTURY DISCOVERY AND INNOVATION

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ACME

- Program information:

  acme.byu.edu

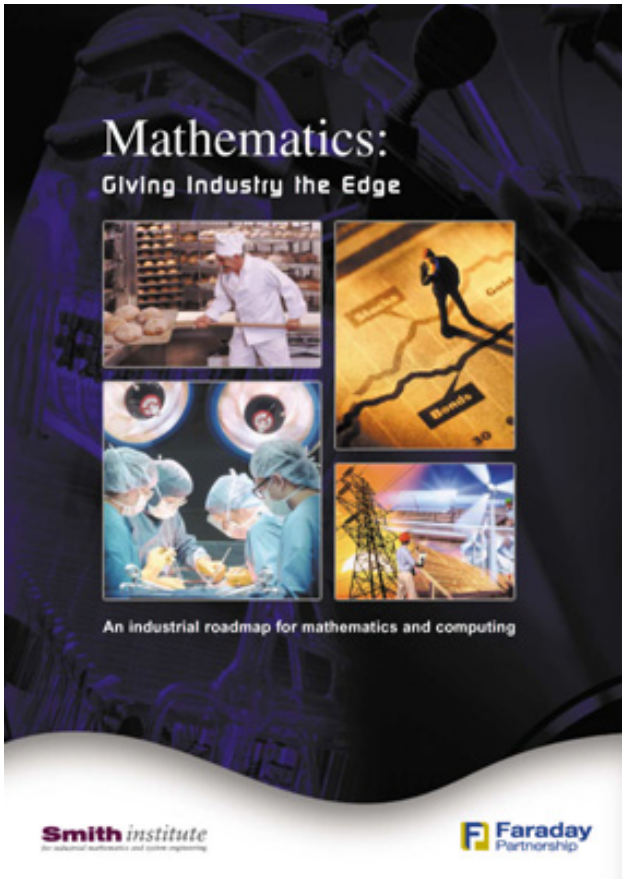
- Labs and other course materials

  foundations-of-applied-mathematics.github.io/

Problems of the 21st Century

(rethinking the curriculum)

- A need for better modeling and simulation methods and technologies
- A workforce more capable of interdisciplinary design.
- Better tools and understanding for analyzing uncertainty and risk
- Greater capabilities for dealing with large data sets.
- New methods for coping with complex systems.
- Improved capabilities for predicting and understanding market behavior.



Attract and Retain Students into Mathematical Sciences through:

- New & Modernized Curriculum
  - Cuts through the jargon of various disciplines
  - Develops a rigorous foundation in mathematics, statistics
  - Gain strong technical skills in both computation and data analytics
- Horizontal Integration Across Multiple Quantitative Disciplines
  - Gives students a broad exposure to several interdisciplinary fields
  - Allows each student to have a primary area of specialization.
- Leadership & Soft-Skills Training
  - Foster socialization and team-building amongst groups of students
  - Networking opportunities with scholars and industry leaders
- Capstone Experience
  - Either undergraduate research or an internship
  - Offers rich opportunities for growth outside of the classroom.
  - Launch into next stage of education or career.

First Year Sequences

Mathematical Analysis

- Vector Spaces
- Linear Transformations
- Inner Product Spaces
- Spectral Theory
- Metric Topology
- Differentiation
- Contraction Mappings
- Integration
- Integration on Manifolds
- Complex Analysis
- Adv. Spectral Theory
- Pseudospectrum

Algorithm Design & Optimization

- Intro Algorithms
- Graph Algorithms
- Discrete Probability
- Fourier Theory
- Wavelets
- Interpolation
- Unconstrained Optimization
- Convex Analysis
- Linear Optimization
- Nonlinear Optimization
- Dynamic Optimization
- Markov Decision Processes

First Year Labs

Mathematical Analysis

- Intro Python
- Complexity/Sparse Matrices
- Linear Systems
- QR
- Markov Chains
- Facial Recognition (SVD)
- Conditioning
- Newton Cotes vs. Monte Carlo
- Sparse Grid Approximation
- Variance Reduction Methods
- Complex Analysis
- Profiling and Wrapping
- PageRank on Tournaments
- Arnoldi Iteration and GMRES
- The Pseudospectrum
- Relational databases and SQL

Algorithm Design & Optimization

- Data Structures
- Depth/Breadth First
- Nearest Neighbor Search
- Scientific Visualization
- Maximum Likelihood Estimation
- FFT and Applications
- Wavelets
- Chebychev Polynomials
- Polynomial Interpolation
- Optimization Packages
- Line Search Methods
- Conjugate Gradient Methods
- Simplex Method
- Compressed Sensing Lab
- Interior Point Methods
- Dynamic Optimization
- Multi-Armed Bandits

Second Year Sequences

Modeling with Uncertainty & Data

- Random Spaces & Variables
- Distributions & Expectation
- Markov Processes
- Information Theory
- Kalman Filtering & Time-Series
- Principal Components
- Clustering
- Bayesian Statistics (MCMC)
- Logistic Regression
- Random Forests
- Support Vector Machines
- Deep Neural Nets

Modeling with Dynamics & Control

- ODE Existence & Uniqueness
- Linear ODE
- Nonlinear Stability
- Boundary-Value Problems
- Hyperbolic PDE
- Parabolic PDE
- Elliptic PDE
- Calculus of Variations
- Optimal Control
- Stochastic Control

Second Year Labs

Modeling with Uncertainty & Data

- Regular Expressions
- Web Technologies
- Scraping with BeautifulSoup
- MPI and OpenMP
- Pandas and Hadoop
- MongoDB/noSQL
- Kalman Filtering
- Time Series
- Naïve Bayes
- Discrete HMMs
- Continuous HMMs (speech recognition)
- Gibbs Sampling and LDA
- Metropolis Hastings
- PCA and LSI
- Clustering with k-means
- Logistic Regression
- Random Forests
- SVM on Handwriting Recognition
- Deep Neural Nets

Modeling with Dynamics & Control

- Harmonic Oscillators and Resonance
- Weightloss Models
- Predator-Prey Models
- Shooting Methods and Applications
- Compartmental Models (SIR)
- Pseudospectral methods for BVP
- Lyapunov Exponents and Lorenz Attractors
- Hysteresis in population models
- Conservation Laws and Heat Flow
- Anisotropic diffusion
- Poisson equation, finite difference
- Nonlinear Waves
- Finite Volume Methods
- Finite Element Methods
- Scattering Problems
- PID Control
- LQR and LQG Control
- Guided Missiles
- Merton Model in Finance

Program Overview

- Freshman & Sophomore Years
  - General Education Requirements
  - Minor in Mathematics (3 Calculus, Linear Algebra, ODE, proof)
  - Intro Computer Programming (C++)
  - First Semester of Real Analysis (Abbott/Blue Rudin)
- Junior Year
  - Mathematical Analysis—Linear and Nonlinear
  - Design, Analysis & Optimization of Algorithms
  - Concentration classes
- Senior Year
  - Modeling w/ Uncertainty & Data
  - Modeling w/ Dynamics and Control
  - Concentration projects

CORE PROGRAM

Growing list of Concentrations

- Biology
- Business Management
- Chemical Engineering
- Chemistry
- Geotechnical engineering
- Structures and structural mechanics
- Transportation
- Water Resources and Environmental Engineering
- Computer Science
- Data Science
- Economics
- Electrical and Computer Engineering: Circuits
- Electromagnetics
- Financial Markets
- Geological Sciences
- Machine Learning
- Manufacturing Systems Design
- Mathematical Biology
- Mathematical Theory
- Mechanical Engineering: Dynamic Systems
- Mechanical Engineering: Fluids and Thermodynamics
- Physics
- Political Science
- Signals and Systems
- Statistics
- Statistics: Actuarial Science
- Statistics: Biostatistics

Leadership and Soft-Skills Training

- Resumes
- Cover Letters
- Interviews
- Internships
- How to give a talk
- Personality Theory
- Listening
- Conflict Management
- Negotiation
- Leadership
- Running a Meeting
- Project Management
- Working in Teams
- Networking

Recent Industry Visits

- Amazon
- Nike
- Raytheon
- Goldman Sachs
- NSA
- Sandia
- Google
- Capital One
- Towers Watson
- Intermountain Healthcare
- UnitedHealth
- MITRE
- Ford
- Recursion

Final Talking Points

- Lock-step approach is Powerful
  - Reuse not review
  - Integration across topics
  - Multi-disciplinary perspective
- Cohort Model is Effective
  - Retention
  - Socialization, Team-Building
  - Strong Alumni Base
  - They become BFFs
- Combines to make an Efficient Program
  - Comes at a cost of 2 FTES (8 courses/year)
  - A few will stay for graduate school at BYU and become TAs

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