Refresher Course Subject Information

Topics Covered - 2024

Applied Calculus (instructor: Chloe Shiff)

- **Scalar Calculus**
  - Chain rule (single and multivariable)
  - Taylor series and Maclaurin series (with and without time dependence)
  - Integration by parts (divergence theorem from n=1)
  - Fundamental Theorem of Calculus
- **Vector Calculus**
  - Vector fields, gradients, Hessian, divergence, curl, Laplacian
  - Divergence theorem (Green's theorem for n=2, integration by parts for n=1), divergence identities, curl identities
  - Dot/inner product, cross product
- **Matrix Calculus**
  - Derivation for some examples, chain rule, gradient, Hessian
  - Integration by parts (multivariable), inner product, cross product
- **Fourier Transform**
  - Definition, examples, and applications

ODEs and PDEs (instructor: Ian Madden)

- **Review of ODEs**
  - Analysis/Exact methods for 1st order equations (Separation of variables, Integrating factors, etc)
  - Picard's Theorem - Numerical methods for 1st order equations (Euler, RK, multistep; stability, consistency, convergence)
  - Systems of 1st order equations - 2nd order equations - Nonlinear equations and linearization (maybe)

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- **PDEs**
  - Where do they come from? (derivations of physical laws, euler-lagrange equations)
  - Examples and intuition (advection equation, conservation laws, diffusion, wave equation, poisson equation)
  - Intro to basic numerical schemes (FD, FV, FE)

Linear Algebra (instructor: Rachel Guo)

- **Matrices**
  - What are matrices used for? (Systems of linear equations, operators, represent networks or graphs)
  - Common matrices
  - Matrix, vector, and matrix-vector operations
  - Matrix and vector norms
  - Matrix inverses and determinants
- **Gaussian Elimination**
  - Elimination and back-substitution
  - LU decomposition
- **Concepts underlying matrix theory**
  - Linear combination of vectors, linear (in)dependence, vector space, span, basis, dimension
  - Column space, row space, matrix rank, null space
- **Eigenvalues and Eigenvectors**
  - Definition of eigenvalues and eigenvectors
  - Diagonalizable matrix and examples

Computing (instructor: Leah Collis)

- Introduction to Stanford Computing
  - Linux and Bash Scripting
  - Git
  - LaTeX
  - MATLAB
  - and other useful software.

Probability and Statistics (instructor: Anish Senapati)

- **Probability**
  - Basic Probability Theory: axioms of probability, events (intersection and union), independence, Bayes' rule
  - Random Variables: intuition behind random variables, discrete and continuous distributions, examples of common distributions, joint distributions, marginal distributions, conditioning, characteristic functions (as moment generating functions)
  - Expectation and higher order moments: mean, variance, moments ofa distribution, covariance, properties of expectation
  - Useful Inequalities: Markov's inequality, Chebyshev's inequality, Jensen'sinequality
  - Convergence: types of convergence, law of large numbers, central limit theorem, delta method
- **Statistics**
  - Estimation: maximum likelihood estimation (MLE), unbiased estimators, minimizing mean squared error, confidence intervals.
  - Statistical Modeling: linear regression, logistic regression
  - Monte Carlo Simulation: concept, implementation, limitations