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| **Course Title** | **Engineering Mathematics for Advanced Studies** |
| **Credit Structure** | L: 3/4, T: 0, P: 0, C: 6/8 |
| **Prerequisite** | NA |
| **Targeted Audience** | Graduate students taking up research activity<br>Research oriented bachelor students interested to hone their skill in specific math modules that they have not worked on extensively in previous courses/research |
| **Objective** | To make the student recall the basics of each course module and show them how it will be applicable for research in engineering domain<br>Expected outcome is the understanding of the basic contents in the respective module in engineering context and with hands-on practice. |
| **Credit allocation** | At least 6 modules to obtain minimum 6 credits.<br>At least 8 modules to obtain 8 credits.<br>Relative grading for each module followed by absolute grading will be adopted for final course grade assessment. |

**Targeted Course Content**

**NOTE – Following is a tentative list of the modules floated for Autumn 2020. Final list will be decided after considering preference from the class.**

**Module selection**

**A) PhD students:** Module selection should be by mutual agreement between student and faculty advisor. Please ensure pre-requisite module completion requirement for each module

**B) MS Students:**

Modules mandatory for MS students-

EE: 1,3,4,6,7,8

ME: 1,2,3,4,5,6

**C) B.Tech. Students:**

Discussion with course instructor (SR) and faculty advisor with consideration to academic load and priorities is required

**Module-1: Linear Algebra:** Linear algebraic equations, Vector Spaces, Orthogonality, Determinants, Eigen-values and Eigen-vectors of matrices, Singular-value decomposition

**Module-2: Ordinary Differential Equations:** Terminology, Solution of Homogeneous and non-homogeneous 1$^{st}$ order linear ODE, Bernoulli, Riccatti and Logistic equations, Solution of Homogeneous and non-homogeneous 2$^{nd}$ order linear ODE, System of 1$^{st}$ order ODE

**Module-3: Vector Calculus:** Dot and Cross Product, Curves, Arc Length, Curvature, Torsion, Divergence and Curl of a Vector Field, Line Integrals, Green's Theorem, Stokes's Theorem, use of Vector Calculus in various engineering streams

**Module-4: Laplace and Fourier transformation:** First and Second Shifting Theorems, Transforms of Derivatives and Integrals, Fourier Cosine and Sine Transforms, Discrete and Fast Fourier Transforms, IVT and FVT significance

**Module-5: Partial Differential Equations:** Basic Concepts of PDEs, Laplace, Poisson, Heat, Wave Equations, Solution by Separating Variables, Solution by Fourier Series, Solution by Fourier Integrals and Transforms, Solution using similarity variable

**Module-6: Numerical Methods:** Methods for Linear Systems, Least Squares, Householder's Tridiagonalization and QR-Factorization, Numerical interpolation, Numerical integration, Methods for Elliptic, Parabolic, Hyperbolic PDEs,

**Module-7: Optimization and Linear Programming:** Introduction to convex sets and functions, and its properties, Important standard classes such as linear and quadratic programming, Lagrangian based method, Algorithms for unconstrained and constrained minimization (example gradient descent).

**Module-8**: **Probability Theory and Statistics:** Experiments, Outcomes, Events, Permutations and Combinations, Probability Distributions, Binomial, Poisson, and Normal Distributions, Distributions of Several Random Variables, Testing Hypotheses, Goodness of Fit, $\chi^2$-Test

**Module-9: Tensor Algebra:** Index Notation and Summation Convection, Levi-Civita symbol, Triple vector product, Tensor Product, Dyads, transpose, trace, contraction, projection, spherical and deviatoric tensors, tensorial transformation laws. Gradient of scalar valued tensor function, Gradient of tensor valued tensor function

**Module-10: Complex Analysis and Potential Theory:** The Cauchy-Riemann Equations, Use of Conformal Mapping, Electrostatic Fields, Heat and Fluid Flow Problems, Poisson's Integral Formula for Potentials

**Texts/References**

**Text Book - E. Kreyszig. Advanced Engineering Mathematics, John Wiley & Sons, 2011.**
A. Schrijver, Theory of Linear and Integer Programming, 1998.
Gilbert Strang, Linear Algebra and Its Applications, 4th Edition, 2004.
Gilbert Strang Differential Equations and Linear Algebra, 2014.
Additional references-
P.V. O'Neil. Advanced Engineering Mathematics, CENGAGE Learning, 2011.
D.G. Zill. Advanced Engineering Mathematics, Jones & Bartlett Learning 2016.
B. Dasgupta. Applied Mathematical Methods, Pearson Education, 2006.

**Instructor (s)**

Prof. SamarthR (SR)

**Departments to whom the course is relevant**

CS/EE/ME

**Justification**

Engineering mathematics is a key-tool necessary for the research students to be good in mathematical methods in order to model and analyze the experimental/computational data. In this course, students learn mathematical techniques in linear algebra, Vector calculus, Laplace and Fourier transformations, ODEs and PDEs, elementary numerical methods, probability foundations. Special modules Tensor algebra and complex numbers are facilitated for those who are interested. Modular structure of this course offers flexibility to students to optimally use this course for their specific needs.

**Summary**

10 modules, modular structure, Course grading - average of grades received in all modules selected by student.

**Time slots:**

Classroom instruction – Online mode

| | **Module Name** | **Instructor** | **Pre-requisite recommendation** (not mandatory) | **Mandatory modules for MS** | |
|---|---|---|---|---|---|
| | | | | **EE** | **ME** |
| 1 | Linear Algebra | TBD | | Y | Y |
| 2 | ODE | TBD | | | Y |
| 3 | Vector Calculus | TBD | | Y | Y |
| 4 | Laplace/Fourier | TBD | 2 | Y | Y |
| 5 | PDE | TBD | 2,4 | | Y |
| 6 | Num. Methods | TBD | 1,2 | Y | Y |
| 7 | OptimizationLPP | TBD | 1 | Y | |
| 8 | Probability&Stats | TBD | | Y | |
| 9 | Tensor Algebra | TBD | 1,3 | | |
| 10 | Complex Analysis | TBD | 2,5 | | |

Course webpage - https://homepages.iitdh.ac.in/~sraut/Au20_EnggMath/index.html