| CODE | COURSE NAME | CATEGORY | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| **222TEE100** | **Computational Techniques in Electrical Engineering** | **Discipline Core -2** | 3 | 0 | 0 | 3 |

**Preamble:**

Numerical computational techniques are indispensable for computing applications in electrical engineering systems. This course is designed with the objective of providing a foundation to the theory behind numerical computation and optimization techniques in electrical engineering systems. This course will equip the students with a mathematical framework for numerical computation and optimization techniques necessary for various computing applications in engineering systems.

**Course Outcomes:** After completing the course the student will be able to

| | |
|---|---|
| **CO 1** | Apply numerical techniques to find the roots of nonlinear equations and solution of system of linear equations. |
| **CO 2** | Apply numerical differentiation and integration for electrical engineering applications |
| **CO 3** | Apply and analyze numerical techniques for solution to differential equation of dynamical systems |
| **CO 4** | Formulate optimization problems and identify a suitable method to solve the same |
| **CO 5** | Solve optimization problems in Electrical Engineering using appropriate optimization techniques |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 |
|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 2** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 3** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 4** | 3 | | 3 | 3 | 3 | 2 | |
| **CO 5** | 3 | | 3 | 3 | 3 | 2 | |

**Assessment Pattern**

| Bloom's Category | End Semester Examination |
|---|---|
| Apply | 40% |
| Analyse | 40% |
| Evaluate | 20% |
| Create | |

**Mark distribution**

| Total Marks | CIE | ESE | ESE Duration |
|---|---|---|---|
| 100 | 40 | 60 | 2.5 hours |

**Continuous Internal Evaluation Pattern: 40 marks**

Micro project/Course based project : 20 marks
Course based task/Seminar/Quiz : 10 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

The project shall be done individually. Group projects not permitted.

**End Semester Examination Pattern:** 60 marks

**Part A:** 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
*Each question can carry 5 marks.*

**Part B:** 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.
*Each question can carry 7 marks.*

**Model Question Paper**

**SLOT A**

**APJ ABDULKALAM TECHNOLOGICAL UNIVERSITY**
**SECOND SEMESTER M.TECH DEGREE EXAMINATION**
**MONTH &YEAR**
Course code: **222TEE100**
Course Name: **Computational Techniques in Electrical Engineering**

**Max. Marks: 60** **Duration: 2.5 Hours**

**PART A**

**Answer all Questions. Each question carries 5 Marks**

1 What is condition number of a matrix. Use condition number to check whether the following matrix is ill-conditioned.

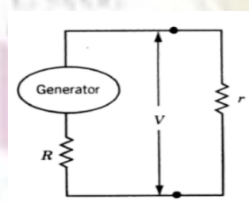
$$A = \begin{bmatrix} 1 & 1/2 & 1/3 \\ 1/2 & 1/3 & 1/4 \\ 1/3 & 1/4 & 1/5 \end{bmatrix}$$

2 Given the points $(0,0), \left(\frac{\pi}{2}, 1\right), (\pi, 0)$ satisfying the function $y = sin\, sin\, x$ $(0 \leq x \leq \pi)$, determine the value of $y(\frac{\pi}{6})$ using the cubic spline approximation.

3 Solve the boundary value problem defined below using finite difference method.
Compare the solution obtained at y(0.5) with the exact value for h=0.5 and h=0.25.

$$y'' - y = 0, \;\; y(0) = 0, y(1) = 1$$

4 An electric generator has an internal resistance of R ohms and develops an open circuit voltage of V volts. Find the value of the load resistance r for which power delivered by the generator will be a maximum. *(Represent the problem as an optimization problem and solve for maximum power.)*




Electric generator with load

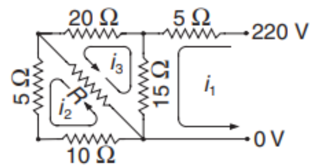
5 State the necessary and sufficient condition for existence of maximum or minimum for a multivariable objective function with constraints.

**PART B**

**Answer any 5 Questions. Each question carries 7 Marks**

6 The electrical network shown can be viewed as consisting of three loops. Apply Kirchoff's law to each loop yields and formulate the system as a classical linear algebraic

system. Compute the loop currents $i_1$, $i_2$ and $i_3$ using LU factorization method, for $R = 10\,\Omega$.




7 Find the zero of y(x) from the following data:

| $x$ | 0 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 |
|---|---|---|---|---|---|---|---|
| $y$ | 1.8421 | 2.4694 | 2.4921 | 1.9047 | 0.8509 | −0.4112 | −1.5727 |

Use Lagrange's interpolation over (a) three; and (b) four nearest-neighbor data points.

8 A second order system is defined by:

$$y'' = -\frac{19}{4}y - 10y', \quad y(0) = -9, y'(0) = 0$$

a. Find the analytical solution for the above system using the eigenvalues of the system
b. Show from (a) that the system is moderately stiff and estimate $\boldsymbol{h_{max}}$, the largest value of $\boldsymbol{h}$ for which the Runge–Kutta method would be stable.
c. Confirm the estimate by computing y(1) with h ≈ hmax/2 and h ≈ 2 hmax.

9 Faraday's law characterizes the voltage drop across an inductor as $V_L = L\frac{di}{dt}$, where $V_L$ is the voltage drop (V), $\boldsymbol{L}$ is the inductance (in Henrys (H)), $\boldsymbol{i}$ is the current (in Amps), and $\boldsymbol{t}$ is the time (in secs). Determine the voltage drop as a function of time from the following data for an inductance of *4 H*.

| Time, t (secs) | 0 | 0.1 | 0.2 | 0.3 | 0.5 | 0.7 |
|---|---|---|---|---|---|---|
| Current, i (Amps) | 0 | 0.1 | 0.32 | 0.56 | 0.84 | 2.0 |

10 Is this a linear or nonlinear programming problem?
Maximize $Z = 3x_1^2 - 2x_2$, subject to the constraints:

$$2x_1 + x_2 = 4$$
$$x_1^2 + x_2^2 \le 40$$
$$x_1, x_2 \ge 0 \quad \text{and are integers.}$$

Solve this problem by a suitable classical method.

11 Minimize $f(x_1, x_2) = x_1 - x_2 + 2x_1^2 + 2x_1x_2 + x_2^2$ from the starting point $X_1 = \{0, 0\}$ using Powell's method.

12 Minimize the function given below using Univariate method method taking $X_1 = \{1, 1\}$ as the starting point.

$$f(x_1, x_2) = 2x_1^2 - x_1x_2 + 3x_2^2$$

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**SYLLABUS**

**Module 1**

**Systems of Linear Algebraic Equations***:* Uniqueness of Solution, Ill conditioning and norms**;** Methods of Solution: Gaussian elimination – LU factorization – Matrix inversion – Gauss-Seidel iteration – least squares method**;** Eigenvalue problems - Power method for eigenvalues – Tridiagonalization and QR factorization

**Module 2**

**Interpolation and Curve Fitting***:* Lagrange's Method, Newton's Method, Cubic Spline**;** Least-Squares Fit, Weighting of Data - Weighted linear regression**;** Roots of Equations: Newton–Raphson Method for systems of equations**;** Numerical differentiation - finite difference and first central difference approximations**;** Numerical integration - trapezoidal and Simpson's rule

**Module 3**

**Solution to differential equations***:* Initial Value Problems - Taylor Series Method, Euler Method, Runge–Kutta Methods-Second-Order and Fourth Order; Stability and Stiffness;

**Two-Point Boundary Value Problems***:* Shooting Method and finite difference method (Concept only)

**Case Study***:* MATLAB/C/ Python programming for solution to differential equations. Two-Point Boundary Value Problems - Shooting Method (Demo/Assignment only)

**Module 4**

Optimization problem, Formulation of optimization problems - linear optimization - Review only.

**Classical Optimization Techniques** Single variable optimization, Multivariable optimization with equality constraints- Direct substitution, method of Lagrange multipliers, Multivariable optimization with equality constraints- Kuhn-Tucker conditions.

**Module 5**

**Non-linear Programming - Unconstrained Optimization Techniques:** Direct Search Methods: Random search methods, Grid search method, Univariate method, Hookes and Jeeves' method, Powell's method; Indirect Search Methods: Steepest descent method, Fletcher-Reeves method, Newton's method.

**Nonlinear Programming - Constrained Optimization Techniques** *(Concepts Only - not for evaluation in the end semester examination)***:** Direct search methods - Random search methods, Basic approach in methods of feasible directions, Zoutendijk's method of feasible directions, Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming.

**Recent developments in optimization techniques** *(Concepts only - Not for evaluation in the end semester examination)*: Genetic Algorithm, Simulated Annealing, Neural Network based optimization, Particle Swarm Optimization, Ant colony Optimization.

**Case studies**- Power system optimization, Optimal control problem, Electrical machine design optimization, Optimal design of Power Electronic converter- **Assignment/Demo only**

References


1. Erwin Kreyszig, Advanced Engineering Mathematics 9th Edition, Wiley International Edition Press, Numerical Recipes for scientific computing.
2. Bhaskar Dasgupta, Applied Mathematical Methods, Pearson.
3. Arfken, Weber and Harris, Mathematical Methods for Physicists, A comprehensive guide, $7^{th}$ Edition, Elsevier, 2013.
4. S.S. Sastry, Introductory methods of numerical analysis, Fifth edition, PHI.
5. Numerical methods in Engineering with MATLAB, Jaan Kiusalaas
6. Singiresu S Rao, *Engineering Optimization Theory and Practice*,5/e, John Wiley&Sons 2020.
7. Edwin K P Chong, Stanislaw H Zak, *An introduction to Optimization*, 2e, Wiley India.
8. Optimization in Electrical Engineering, Mohammad Fathi, Hassan Bevrani, Springer


**COURSE PLAN**

| No | Topic | No. of Lectures |
|---|---|---|
| **1** | ***Systems of Linear Algebraic Equations*** | **9 hrs** |
| 1.1 | Uniqueness of Solution, Ill conditioning and norms | 1 |
| 1.2 | Methods of Solution: Gaussian elimination – LU factorization – Matrix inversion | 3 |
| 1.3 | Gauss-Seidel iteration – least squares method | 2 |
| 1.4 | Eigenvalue problems - Power method for eigenvalues – Tridiagonalization and QR factorization | 3 |
| **2** | ***Interpolation and Curve Fitting*** | **8 hrs** |
| 2.1 | Lagrange's Method, Newton's Method, Cubic Spline**;** Least-Squares Fit | 3 |

| | | |
|---|---|---|
| 2.2 | Weighting of Data - Weighted linear regression | 1 |
| 2.3 | Roots of Equations: Newton–Raphson Method for systems of equations | 1 |
| 2.4 | Numerical differentiation - finite difference and first central difference approximations | 2 |
| 2.5 | Numerical integration - trapezoidal and Simpson's rule | 1 |
| **3** | ***Solution to differential equations*** | **7 hrs** |
| 3.1 | Initial Value Problems - Taylor Series Method | 1 |
| 3.2 | Euler Method | 1 |
| 3.3 | Runge–Kutta Methods - Second-Order and Fourth Order | 2 |
| 3.4 | Stability and Stiffness. | 1 |
| 3.5 | *Two-Point Boundary Value Problems:* Shooting Method and finite difference method (Concept only)<br><br>*Case Study:* Two-Point Boundary Value Problems - Shooting Method (Demo/Assignment only) | 2 |
| **4** | ***Formulation of Optimization problems and its solutions using classical methods*** | **7 hrs** |
| 4.1 | Optimization problem, Formulation of optimization problems - linear optimization - Review only. | 1 |
| 4.2 | Constrained Linear Optimization- Single variable optimization | 1 |
| 4.3 | Multivariable optimization - Direct substitution | 1 |
| 4.4 | Method of Lagrange multiplier, Necessary and sufficient conditions - Problems | 2 |
| 4.5 | Equality and inequality constraints, Kuhn -Tucker conditions (*both linear and nonlinear)* – Problems | 2 |
| **5** | ***Nonlinear - Unconstrained and constrained Optimization Techniques*** | **9 hrs** |
| 5.1 | Nonlinear Optimization problem - Unconstrained and Constrained problems | 1 |

| | | |
|---|---|---|
| 5.2 | Unconstrained Problems: Direct search methods - Random search- pattern search - Grid Search methods. *(Concepts only for Constrained Optimization.)* | 2 |
| 5.3 | Unconstrained - Univariate method, Hookes and Jeeves' method, Powell's method. | 2 |
| 5.4 | Indirect search methods: Descent Methods-Steepest descent, conjugate gradient, Fletcher- Reeves method. | 2 |
| 5.5 | *(Constrained Optimization - Concepts only - Not for evaluation)* Zoutendijk's method of feasible directions, Rosen's gradient projection method, Generalized Reduced gradient method, Sequential quadratic programming. | 2 |