AE 6310 Optimization for the Design of Engineered Systems
Topic Outline and Instruction Hours

1) **Introduction (2 hrs)**
   - **a)** Need for numerical optimization in engineering design
   - **b)** Review of multivariate calculus fundamentals

2) **Unconstrained Optimization (10 hrs)**
   - **a)** Necessary and sufficient conditions for a local optimum
   - **b)** Line search algorithms
     - **i)** Zeroth order (Powell's method, univariate search)
     - **ii)** First order (steepest descent, conjugate gradient, BFGS, etc.)
     - **iii)** Second order (Newton's method)
   - **c)** Direct search algorithms (random walk, coordinate pattern search, etc.)
   - **d)** Normalization approaches and convergence criteria

3) **Constrained Optimization (10 hrs)**
   - **a)** Challenges of constraints; activity, feasibility
   - **b)** KKT necessary conditions
   - **c)** Indirect methods and penalty functions (interior, exterior, augmented Lagrangian, etc.)
   - **d)** Linear programming and the simplex method
   - **e)** Direct methods (SLP, MoFD, generalized reduced gradient method, SQP, etc.)

4) **Metaheuristic Optimization (5 hrs)**
   - **a)** Metropolis algorithm and simulated annealing
   - **b)** Binary representation (decimal/binary conversion, Hamming distance, Gray codes)
   - **c)** Genetic operators and algorithms (selection, crossover, mutation, replacement)
   - **d)** Particle swarm algorithms

5) **Multi-Objective Optimization (2 hrs)**
   - **a)** Partial ordering and Pareto dominance
   - **b)** Aggregate objective function (AOF) approach
   - **c)** ε-constraint method
   - **d)** Normal boundary intersection (NBI) and related methods
   - **e)** Multi-objective genetic algorithms (NSGA-II, etc.)

6) **Multidisciplinary Optimization (4 hrs)**
   - **a)** Multidisciplinary analysis (MDA): partitioning, interaction, coupling, consistency
   - **b)** Design Structure Matrices (DSM)
   - **c)** Fixed-point iteration (Gauss Seidel)
   - **d)** Single-level MDO architectures (MDF, IDF)
   - **e)** Multi-level/hierarchical MDO architectures (CO, ATC)

7) **Designs of Experiments and Surrogate Models (4 hrs)**
   - **a)** Full and fractional factorial designs
   - **b)** Space filling designs (LHC, minimax and maximin, maximum entropy, uniform)
   - **c)** Multiple linear regression models: polynomials and radial basis functions (RBFs)
   - **d)** Nonlinear regression models: artificial neural networks (ANN) and Gaussian processes
   - **e)** Assessing fit quality: error measures, validation sets, cross-validation, overfitting
   - **f)** Regularization methods

8) **Robust Design Methods (3 hrs)**
   - **a)** Taguchi methods
   - **b)** Probabilistic methods in robust design; approaches for uncertainty propagation
   - **c)** Reliability-based design optimization (RBDO)

9) **Bayesian Global Optimization (2 hr)**
   - **a)** Philosophical approach involving Bayesian surrogate models
   - **b)** Expected improvement criterion
   - **c)** Efficient Global Optimization (EGO)

Exams and Reviews: 2 hr
Total Course Hours: 44 hr