# Screening Exam Topics

## Academic Year 2019 - 2020

The Screening Exam aims to achieve three objectives:

(i) To determine if the student has a deep understanding of the basic knowledge of at least two areas of emphasis in Mechanical Engineering.

(ii) To determine if the student has the mathematical skills required for a deep understanding of the basic knowledge of the two areas of emphasis.

(iii) To assess if the student has the analytical ability and critical thinking skills required to embark on independent research in one area of emphasis.

The Screening Exam is meant to test the student's broad understanding of fundamental concepts and the student's ability to draw connection inside and across disciplines. The following list of courses and reading material are not to be understood as *required* courses and *assigned* reading, but rather as *suggested* courses and reading. The aim of the screening exam is not to merely assess whether or not students have memorized the content of the suggested courses or reading materials. The suggested courses or reading materials are thus to be understood as an indicator of the type of material, breadth and level that is expected from the candidates.

**Important note**: This document pertains only to the Spring 2020 and Fall 2020 screening exams. Successive exams will be based upon revised versions of this document.

# Area 1: Bio-Engineering and Systems Biology (BESB)

**Topics:**

(i) Biomechanics and mechanobiology

  (a) Cytoskeleton
  (b) Molecular motors
  (c) Cell adhesion

(ii) Systems Biology

  (a) DNA, RNA and protein regulation
  (b) Signaling cascades

**Suggested Reading Material:**

(i) Phillips *et al. Physical Biology of the Cell*, Ed. 2. Chapters 10, 13 and 19.

(ii) Howard. *Mechanics of Motor Proteins and the Cytoskeleton.* Chapters 4, 5, 7-15.

**Suggested Courses:**

(i) ENGR 220A - Molecular BioEngineering (Winter)

(ii) ENGR 220B - Cellular BioEngineering (Spring)

# Area 2: Computational Science and Engineering (CSE)

**Topics:**

(i) Numerical methods for nonlinear initial value problems for ODEs

- (a) Basic Methods: Euler's method, modified Euler and backward Euler
- (b) Runge Kutta methods
- (c) Multistep and predictor corrector methods
- (d) Stability properties
- (e) Stiffness

(ii) Numerical Methods for Partial Differential Equations using Finite Difference Methods

- (a) Standard Methods for Hyperbolic, Elliptic and Parabolic Partial Differential Equations
- (b) Consistency and Stability Analysis, Well-Posedness
- (c) Order of Accuracy
- (d) Dissipation and Dispersion
- (e) Systems of PDEs in Higher Dimensions

**Suggested Reading Material:**

(i) U. M. Ascher and L. R. Petzold. *Computer Methods for Ordinary Differential Equations and Differential-Algebraic Equations*, SIAM, 1998. Ch 1-5

(ii) J. Strikwerda. *Finite Difference Schemes and Partial Differential Equations*, SIAM, 2 edition, 2004. Ch 1-9

**Suggested Courses:**

(i) ME 210B "Numerical Simulation" (Winter)

(ii) ME 210C "Numerical Solution of PDEs with Finite Difference Methods" (Spring)

# Area 3: Dynamics, Control and Robotics (DCR)

**Topics:**

(i) Basic models: linear, nonlinear, solutions, equilibria, limit cycles, phase portraits

(ii) Stability analysis: asymptotic, linearization, Lyapunov

(iii) Controllability, stabilizability, observability and detectability

(iv) Invariant manifolds: stable, unstable, center

(v) Bifurcation analysis

**Suggested Reading Material:** The following chapters contain a superset of the required topics.

(i) C. T. Chen "Linear Systems: Theory and Design," 3rd edition, Oxford, 1999, Ch 1-8
or, alternatively,
J. Hespanha "A Course in Linear Systems Theory", Selected topics in Part I, II, III and IV

(ii) S. Wiggins. "Introduction to Applied Nonlinear Dynamic Systems and Chaos", Texts in Applied Mathematics. Springer, 2nd edition, 2003. Ch 1, 2, 3, 18, 20, 21

(iii) H. K. Khalil. "Nonlinear Systems", Prentice Hall, 3 edition, 2002. Ch 1, 2, 3

**Suggested Courses:**

(i) ME 243A "Linear Systems I" (Fall)

(ii) ME 215A "Applied Dynamical Systems I" (Fall)

Alternative and supplementary course: ME 236

# Area 4: MicroElectroMechanical Systems (MEMS)

**Topics:**

(i) Electrostatics and Magnetostatics

(ii) Maxwell's Equations

(iii) MEMS applications

(iv) Fabrication of Micro/Nanosystems

(v) Design of Micro/Nanosystems

**Suggested Reading Material:**

(i) U.S. Inan and A.S. Inan "Engineering Electromagnetics". Ch 4,5,6,7

(ii) M. Madou "Fundamentals of Microfabrication". Ch 1-4 (1-44, 77-118, 123-135, 183-205)

(iii) S. Senturia "Microsystem Design". Ch 1,3,7,8,19

**Suggested Courses:**

(i) ME 291A "Physics of Transducers" (Fall)

(ii) ME 292 "Design of Transducers" (Spring)

# Area 5: Solid Mechanics, Materials and Structures (SMMS)

**Topics:** Roughly half of the exam will cover topics in continuum mechanics and the other half will emphasize applications to materials including principles of elasticity, plastic deformation and fracture mechanics.

(i) Continuum Mechanics

- (a) Stress/strain notions, balance equations, principal stresses, invariants
- (b) Displacement fields and small strain theory
- (c) Virtual work, isotropic elastic stress/strain relations
- (d) Constitutive laws, elastic potential energy

(ii) Deformation and Fracture

- (a) Elastic properties
- (b) Dislocations, slip and dislocation mechanics
- (c) Yielding and strain hardening
- (d) Strengthening mechanisms
- (e) Linear elastic and fracture mechanics
- (f) Fracture of metals and brittle solids
- (g) Fatigue and fatigue crack growth

**Suggested Reading Material:**

(i) Continuum Mechanics Online Notes, available at `http://motion.me.ucsb.edu/GradProgram`

(ii) T. H. Courtney "Mechanical Behavior of Materials," pp. 1-210

(iii) T.L. Anderson "Fracture Mechanics, Fundamentals and Applications," 2nd Edition, CRC Press, 1995, Ch 2 "Linear Elastic Fracture Mechanics," pp. 31-96. (optional)

**Suggested Courses:**

(i) ME 219 "Mechanics of Materials" (Fall)

(ii) ME 264 "Mechanical Behavior of Materials" (Winter)

# Area 6: Fluid and Thermo Sciences (FTS)

**Topics:**

(i) General conservation laws

(ii) Transport phenomena (diffusion and convection) for mass, momentum and energy

(iii) Incompressible flows and introductory topics on compressible flows

(iv) Laminar flows and introductory topics on turbulent flows

(v) Boundary layer theory

**Suggested Reading Material:**

(i) W. M. Deen "Analysis of Transport Phenomena"

(ii) R. L. Panton "Incompressible Flow"

(iii) J. D. Anderson "Modern Compressible Flow", 3rd ed

General conservation laws: Deen Ch 2, Panton Ch 5, Anderson Ch 2
Transport phenomena: Deen Ch 4-6, Panton Ch 6, Deen Ch 9-10
Incompressible flows: Panton Ch 10-11 18, 21
Boundary layer: Panton Ch 20, Deen Ch 8
Turbulence: Panton Ch 23, Deen Ch 13
Compressible flows: Anderson Ch 3

**Suggested Courses:**

(i) ME 220A "Fundamentals of Fluid Mechanics I" (Fall)

(ii) ME 220B "Fundamentals of Fluid Mechanics II" (Winter)