

TOPICS COVERED:
MATERIALS & STRUCTURES SECTION OF UNIFIED
(Compiled by PAL for 16.20 students)

The following is a summary of key topics, concepts, tools, and approaches presented in Unified Engineering that are pertinent to the material and learning in 16.20. Most of this material was presented in the Materials & Structures section of Unified. A minor fraction was taught in the "Unified" or "Dynamics" sections of Unified.

Students are expected to understand and be able to apply these items at the level presented and exercised within Unified Engineering. There will be reviews of this material prior to extension thereof, but the primary responsibility for the review and renewal of capability is the student's. Help in this regard is available through the teaching staff.

The pertinent topics are:

- Intro; definition of structures and solid mechanics; purpose(s) of structural engineering; modeling; 3 principles of solid mechanics (equilibrium, compatibility, constitutive relations).
- Dimensions and units; coordinate systems; concept of force; forces: line of action, summation of forces; scalar/dot product; vector/cross product; vector transformation; D'Alembert's Principle; static equilibrium.
- Moments; moment about a point, moment about an axis, couples.
- Equilibrium of a particle; equilibrium of a system: force and moment; planar force systems; equipollent force systems; support and reaction forces, "standard" supports/boundary conditions.
- Free body diagram; steps in solving static equilibrium problems; static determinance (dynamic, statically determinate, statically indeterminate), examples.
- Planar trusses, idealizations/assumptions; truss analysis: reaction forces, method of joints, method of sections, examples; extension to 3-D trusses.
- (External) Static determinance, internal determinance, internal equilibrium; "Simple" statically indeterminate structures, examples.

- Indicial notation; coordinate transformations.
- Concept of stress; stress tensor; convention for stress; symmetry of stress tensor; equilibrium of infinitesimal element, equations of equilibrium; plane stress.
- Transformation of stress, Mohr's circle; principal stress, principal axes, maximum shear stresses
- Concept of strain; strain tensor; elongation strains, shear strains; strain-displacement (linear), linear (small) strain; strain compatibility.
- Transformation of strain, Mohr's circle, 1st and 2nd order tensor transformations, examples; principal strain, direction, maximum shear strain.
- Material properties; classes of materials (metals, ceramics, polymers, composites).
- Origin of elastic properties; structures of materials: atomic bonding, packing of atoms, crystals, polymers; composites.
- Modulus limited design, materials selection; measuring engineering properties.
- Stress-strain relations, constitutive properties; anisotropy, orthotropy; measurements.
- Engineering notation, compliance matrix, compliance tensor, elasticity tensor (2-D and 3-D), generalized Hooke's law.
- Types of boundary conditions (displacement, traction); solution approaches in elasticity.
- Definition of a rod; tension in a rod: stresses and deflections; St. Venant's Principle; beams: definition, model, force system convention, shears, bending moments; Shear and Moment diagrams; equilibrium of beam infinitesimal element, relations between Q , S , M .
- Simple Beam theory, assumptions, equation derivation; definition of resultants, moment-curvature relation, solution for stresses; statically indeterminate beams.
- Moment of area, moment of inertia; beam centroid; moment of inertia for general symmetric cross-section, parallel axis theorem; moment of area for general symmetric section; flange/web model; typical cross-sections.
- Torsion of a (circular) shaft: definitions, assumptions, strains and stresses, equation derivation; polar area moment of inertia; torque-twist relationship; solution for stresses.
- General concept of stability, definition of elastic instability; stability of discrete systems, examples; buckling/bifurcation, eigenvalues/vectors and buckling

loads/modes; continuous systems - - buckling of a column, derivation of governing equation.

- Solution for column buckling, application of boundary conditions, Euler buckling load, cantilever case (nonhomogeneous equation), other boundary conditions.
- Types of imperfections; deflection of column under eccentric loading; crushing; effective length; general behavior of column.
- Concept of yielding; the stress-strain curve: brittle vs. ductile behavior; definition of yield stress; test for yield stress, necking, true strain and engineering strain.
- Material origins of strength; strength of perfect crystals: atomic energy curve; weakest link analogy; dislocations; methods to stop/delay yielding (i.e. hardening).
- Yielding and shear stress; yielding at structural level; von Mises criterion; Tresca condition, examples.
- Creep and creep rupture, effects of time and temperature; viscoelasticity and viscoplasticity.
- Fracture and fracture mechanics; concept of stress concentrations; stress at crack tip; energy of fracture; fracture toughness; cleavage, micromechanisms of fracture; actual mechanisms of fracture.
- Griffith criterion, Linear Elastic Fracture Mechanics (LEFM), critical stress intensity factor; inherent flaws; stress intensity factor and geometric factor; examples of uses of LEFM.
- Fatigue--what it is, low cycle and high cycle, concept of S-N curves; mechanisms of fatigue, crack nucleation/initiation and crack growth; definitions for cyclic stress; S-N curves, effects of stress concentration, endurance/fatigue limit.
- Materials selection, considerations, functional requirements to materials requirements, modeling and "figures of merit"; solution process; "design" of materials.