Problem Statements for Homeworks and Quizzes

Beginning through Final Exam

Chapter 1:

1. A 1-inch diameter, 1-foot long rod is subjected to a tensile force of 2000 lb. The rod is made of 6061-T6 Aluminum with E = 10,000 ksi, v=0.33, and G=3,770 ksi.
   a. Calculate the average normal stress in the rod (psi): ___
   b. Calculate the average normal strain in the rod (in/in): ___

2. The rod from problem 1 is instead subjected to a torsional moment of 10,000 ft-lb.
   a. Calculate the maximum shear stress in the rod (psi): ___
   b. Calculate the angle of twist (rad): ___

3. A hollow cylinder with length 1 m, inner radius 4 cm, and thickness 1 mm is subjected simultaneously to a bending moment of 100 N-m and a torsional moment of 150 N-m.
   a. Find the maximum normal stress due to bending (MPa): ___
   b. Find the maximum shear stress due to torsion (MPa): ___
   c. Use Mohr's Circle to find the maximum principle stress and maximum shear stress due to the combined loading (MPa): ___ & ___.

4. A cantilever beam is 4 feet long, with a rectangular cross-section having width 2 inches and height 4 inches. The beam is subjected to an end load of 1500 lb oriented at an angle of 30 degrees with respect to the axis of the beam. The horizontal component of force acts to put the beam in tension, while the vertical component acts in the direction of the 4in height.
   a. Find the maximum normal stress due to tension (psi): ____
      - The stress is (select one):
        (A) maximum at the top surface of the beam;
        (B) maximum at the centroid of the beam;
        (C) maximum at some other location;
        (D) uniform throughout the whole cross-section of the beam; or
        (E) not enough information to answer this question.
   b. Find the maximum shear stress due to transverse shear forces (psi).
      - The stress is (select one): [same 5 options]
   c. Find the maximum normal stress due to bending (psi).
      - The stress is (select one): [same 5 options]

5. A simply-supported beam is 5 feet long, with a 3x3 inch square cross-section. The beam supports a uniform (i.e. rectangular) distributed load of 100 lb/in that spans the whole length of the beam.
   a. Use shear and bending moment diagrams to find the maximum bending moment in the beam (in-lb): ___
   b. If the beam is made of 17-4-PH stainless steel with a yield strength of 125 ksi, find the safety factor for the maximum stress in the beam to avoid yielding (ksi/ksi): ___

Quiz Problem:

Consider a beam of length L, with simple supports at each end. The beam is subjected to 4 point bending, in which two equal point loads, P, are applied symmetrically to the top of the beam and separated by a distance d < L. Solve for the reaction forces at each support, then use shear force and bending moment diagrams to show that the shear force between the two point loads is zero, and therefore all stress in this region can be due only to a uniform bending moment.

Chapter 5:

1. Solve problems 5.15-5.16 from your textbook, then plug in the following values to submit your final answers. Take P = 10 kN, E = 68.9 GPa, I = 4.2*10^6 mm^4, L = 70 cm, and R = 50 cm.
    a. Determine the vertical deflection of point A (mm): ___
    b. Determine the change in slope of point A (rad): ___

2. Solve problem 5.34 from your textbook, then plug in the following values to submit your final answer. Take wmax = 180 lb/ft, L = 2.5 ft, E = 9,990 ksi, and I = 12.5 in^4. Neglect shear.
    a. Determine the deflection at the center of the beam (in): ___

3. Solve problem 5.51 from your textbook.
    a. Determine the rotation at the free end of the shaft (rad): ___

4. Solve problem 5.64 from your textbook. Take Mc = 150 kN-m, L = 0.5 m, E = 200 GPa, and I = 5.6*10^6 mm^4.
    a. Determine the reaction at B (kN): ___
    b. Determine the slope of the beam over the support at B (rad): ___

5. Solve problem 5.67 from your textbook, then plug in the following values to submit your final answer. Take w = 110 lb/in, L = 16 in, H = 10 in, I1 = 11.667 in^4, and I2 = 2.667 in^4.
    a. Solve for the horizontal reaction of the pin at D (lb):

Quiz problem:

A beam of length L is supported at the left by a fixed end. A uniformly distributed load w is applied across the entire length of the beam. The beam has material properties E and G, and area properties A, I, and J. Find the slope at the free end of the beam. Use Castigliano. Neglect shear.

(In other words: repeat Example 5.8 except solve for the slope at the free end instead of the deflection.)

Chapter 2:

1. Solve problem 2.1 from your textbook.

a. Find the x-component of the traction vector, tx (MPa): ___
b. Find the y-component of the traction vector, ty (MPa): ___
c. Find the z-component of the traction vector, tz (MPa): ___
d. Find the magnitude of the shear component of the traction vector, ts (MPa): ___

2. Solve problem 2.10 from your textbook.
   a. Determine the first principal stress (MPa): ___
   b. Determine the second principal stress (MPa): ___
   c. Determine the third principal stress (MPa): ___
   d. Calculate the maximum shear stress (MPa): ___
   e. Calculate the octahedral shear stress (MPa): ___
   f. Determine the angle between the x axis and X axis, where X is the direction of the first principal stress (degrees): ___

3. Solve problems 2.18 and 2.22 from your textbook.
   a. Determine the first principal stress (MPa): ___
   b. Determine the second principal stress (MPa): ___
   c. Determine the third principal stress (MPa): ___
   d. Calculate the maximum shear stress (MPa): ___
   e. Determine the angle between the x axis and X axis, where X is the direction of the first principal stress (degrees): ___
   f. Determine sigma_XX at the orientation defined in Problem 2.22 (MPa): ___
   g. Determine tau_XY at the orientation defined in Problem 2.22 (MPa): ___

4. Solve problems 2.56 and 2.57 from your textbook.
   a. Determine the normal strain, epsilon_xx, for the (x,y) coordinate axes: ___
   b. Determine the normal strain, epsilon_yy, for the (x,y) coordinate axes: ___
   c. Determine the tensor shear strain, epsilon_xy, for the (x,y) coordinate axes: ___
   d. Determine the normal strain, epsilon_XX, for the (X,Y) coordinate axes: ___
   e. Determine the normal strain, epsilon_YY, for the (X,Y) coordinate axes: ___
   f. Determine the tensor shear strain, epsilon_XY, for the (X,Y) coordinate axes: ___
   g. Find the first principal strain: ___
   h. Find the second principal strain: ___
   i. Find the third principal strain: ___
   j. Determine the orientation of the first principal axis with respect to the (x,y) coordinates (degrees CW).

5. Solve problem 2.77 from your textbook.
   a. Determine the first principal surface strain (microstrain): ___
   b. Determine the last principal surface strain (microstrain): ___
   c. Determine the direction of the principal axis (degrees CW): ___
   d. Determine the maximum shear strain (microstrain): ___

Quiz Problem:

A point under stress has sigma_xx = 90 ksi, sigma_yy = 60 ksi, tau_xy = 20 ksi, and all other stresses are zero. Find the three principle stresses and the maximum shear stress.

Chapter 2 Proofs:

Those who complete the following 5 proofs can have them replace their lowest homework score:

1) Draw a free body diagram of the stresses acting on a differential cube of dimensions dx, dy, and dz. Use this to derive equations (2.45). (NOTE: For readability, it is ok to just draw the forces acting in one direction.)

2) Following the procedure in section 2.4.4, derive the equations for the octahedral stresses in (2.23).

(HINT: Step 1: Follow the opening paragraph to derive (2.22) in terms of σ_1, σ_2, and σ_3.

Step 2: Express (2.22) in terms of the invariants so it can be used for any coordinate system.

Step 3: Plug in the invariants to express (2.23) for any x, y, z coordinate system.)

3) Starting from the mean and deviatoric stresses in equations (2.26), solve for the invariants of T_D to derive equations (2.27). (HINT: the invariants of the full stress tensor, T, are given in equation (2.21).)

4) Starting from the small-displacement strains in equations (2.81), derive the compatibility relations in (2.83). (HINT: The first derivation is given in the text.)

5) Derive equations for ε_{xx}, ε_{yy}, and ε_{xy} as functions of ε_a, ε_b, and ε_c for the delta rosette in Figure 2.20(a). (HINT: using tensor shear strains ε_{xy} instead of engineering shear strains γ_{xy}, the 2D transformation equation for ε_{xx} has the same form as the transformation for σ_{xx} in equation (2.30).)

Chapter 3:

This problem set is worth half as many points as most others.

1. A cylindrical rod is loaded in pure torsion until a strain gauge mounted at a 35 degree angle reads 3000 microstrain. The rod is made of 6061-T^ aluminum with E = 10,000 ksi and v = 0.33.
    a. How much torsional stress was applied? (ksi): ___

2. A cylindrical pressure vessel is loaded such that the hoop stress is sigma_xx = pr/t = 40 MPa and the longitudinal stress is sigma_zz = pr/2t = 20 MPa. The cylinder is additionally loaded in torsion with tau_xz = Tr/J = 15 MPa. The cylinder is made of 316 stainless steel with E = 190 GPa, v = 0.265, and G = 74 GPa.
    a. Find the first principal strain (microstrain): ___
    b. Find the second principal strain (microstrain): ___
    c. Find the third principal strain (microstrain): ___
    d. Find the maximum shear strain (microstrain): ___

3. A strain gauge rosette having thetaA = 30 degrees, thetaB = 60 degrees, and thetaC = 90 degrees is mounted to the surface of a part. The part is loaded in uniform thermal expansion such that exx = eyy = 200 microstrains and exy = 0. What should the gauges read? (HINT: You can solve this problem with trig, but think about what a strain gauge does and what deformation is applied.)
    a. Gauge A (microstrain): ___
    b. Gauge B (microstrain): ___
    c. Gauge C (microstrain): ___

Quiz Problem:

A flat tensile specimen is in plane stress, with sigma_yy non-zero and all other stresses zero. A rectangular strain rosette is mounted to the specimen with gauge A in the x-direction, gauge C in the y-direction, and gauge B halfway in between. Using the strain transformation equations and Hooke's law, derive expressions to measure Young's Modulus and Poisson's Ratio using only the applied stresses and any strain gauge measurements. Simplify your fractions as far as you can in order to receive full credit.

Chapter 6:

1. Solve problem 6.17 from your textbook.
   HINT: If the maximum yield stress of a material is Y (measured from a uni-axial tension test), then Mohr's circle says the maximum allowable shear stress for that material is Y/2.
   The safety factor is the ratio between the [max stress allowed by the material] divided by the [max stress allowed by the design].
    a. Determine the maximum Torque that can be safely applied (N-M)

2. Solve problem 6.20 from your textbook.
    a. Find the maximum shear stress (MPa)
    b. Find the angle of twist per unit length (rad/m)

3. Solve problem 6.42 from your textbook.
   NOTE: 80mm and 60mm are the outer dimensions of the rectangle.
    a. Determine the maximum shear stress (MPa)

4. Solve problem 6.45 from your textbook.
   NOTE: 80mm and 140mm are the outer dimensions of the rectangle. 60mm is the outer diameter of the semi-circle.

    a. Determine the maximum shear stress (MPa)
    b. Determine the angle of twist per unit length (rad/m)

5. Solve problem 6.57 from your textbook.
   NOTE: The dimensions given are the distances to the mid-lines of the cross-section.
    a. Determine the maximum shear stress (MPa)
    b. Determine the angle of twist (rad)

Quiz Problem: A beam has the cross-sectional geometry from problem 8.18 (chapter 8 is not a typo), and a shear modulus of G=75 GPa. The dimensions given are all outer dimensions. The beam is subjected to a torque of T=500 N-m. Find (a) the torsional constant, J; (b) the maximum shear stress, tau_max; and (c) the angle of twist per unit length, theta.

Chapters 7 & 8

1. Solve problem 8.18 in your textbook.
   HINT: If you get stuck, you can check your work against Table 8.1, but I recommend practicing the long way so you actually learn the material.
    a. Locate the shear center (mm, as defined in Figure B of Table 8.1).

2. Solve problem 8.20 in your textbook.
   HINT: If you get stuck, you can check your work against Table 8.1, but I recommend practicing the long way so you actually learn the material.
    a. Locate the shear center (mm, as defined in Figure A of Table 8.1).

3. Solve problem 7.4 in your textbook.
    a. Determine the magnitude of the maximum flexural stress for the section (MPa)

4. Solve problem 7.20 in your textbook.
    a. Calculate the maximum tensile stress in the beam (MPa)
    b. Calculate the maximum compressive stress in the beam (MPa)
    c. Determine the orientation of the neutral axis (rad)

5. Solve problem 7.27 in your textbook.
    a. Determine the maximum flexure stress in the beam.

Quiz Problem: A beam has the cross-sectional geometry from Pb 6.42 (chapter 6 is not a typo), and is loaded vertically such that the plane of loads is at phi=0. (a) Find the orientation of the neutral axis, and (b) label the locations of the maximum tensile and compressive stresses.

Chapter 9

This problem set is worth half as many points as most others.

1. Solve problem 9.7 in your textbook.
    a. Determine the stress at B for P=20kN [MPa]

2. Solve problem 9.17 in your textbook.
   HINT 1: Safety Factor = [max allowed by material] / [max allowed by design]
   HINT 2: For part b, the maximum radial stress occurs at the base of the cut-out, r=70+60 mm
    a. Determine the maximum value of P [kN]
    b. Determine the radial stress when this load P is applied [MPa]
    c. Is the maximum radial stress less than the maximum circumferential stress?

3. Solve problems 9.20 and 9.21 in your textbook.
   Ignore Bleich factors. Section 9.4 is not covered in this course.
    a. Determine the circumferential stress at B [MPa]
    b. Determine the circumferential stress at C [MPa]
    c. Determine the radial stress at the junction of the web and inner flange [MPa]

Quiz Problem: Repeat Problem 9.17(a) using the same dimensions, except the direction of the U-shaped cross-section is flipped such that the middle of the U-shape is at the outer radius instead of the inner. Compared to 9.17(a) as-written, which can tolerate higher force?

<u>**Chapters 4 & 12**</u>

1. Solve problem 4.9 in your textbook.
    a. Determine the factor of safety used in the design, assuming the **Tresca** criterion is used.
    b. Determine the factor of safety used in the design, assuming the **Von Mises** criterion is used.

2. Solve problems 4.31-4.32 in your textbook.
    a. Determine the diameter of the crankshaft if it is designed using the **maximum shear stress** criterion and SF=2.00 (mm).
    b. Determine the diameter of the crankshaft if it is designed using the **maximum octahedral stress** criterion and SF=2.00 (mm).

3. Solve problem 4.36 in your textbook. (Note: part c goes onto the next page).
    a. Determine the factor of safety for a design based on the **octahedral shear stress** criterion.
    b. Determine the factor of safety for a design based on the **maximum shear stress** criterion.
    c. Determine the maximum principal stress which acts at point B as shown (MPa)
    d. Determine the minimum principal stress which acts at point B as shown (MPa)
    e. Determine the orientation of the maximum principal stress which acts at point B as shown (degrees CCW)

4. Solve problem 12.6 in your textbook.
    a. Determine the critical buckling load for the **solid square** cross-section (kN).
    b. Determine the critical buckling load for the **solid circle** cross-section (kN).
    c. Determine the critical buckling load for the **hollow circle** cross-section (kN).

5. Solve problem 12.8 in your textbook.
    a. Determine the magnitude of P that will first cause one of the columns to buckle (kN).

Quiz Problem: A component is built using 17-4 PH steel, with E = 28.5 Msi and Y = 170 ksi. The component is loaded with the same stress state as assigned in the quiz for chapter 2. Find the safety factors to prevent yielding under the (a) maximum normal stress criterion, (b) Tresca criterion, and (c) Von Mises criterion.

<u>Chapters 14 & 15</u>

1. Solve problems 14.1 and 14.2 from your textbook.
   a. Problem 14.1: Which value of Scc is most correct when the flat bar is loaded in tension? (multiple choice)
   b. Problem 14.2a: Which value of Scc is most correct when the flat bar is loaded in tension? (multiple choice)
   c. Problem 14.2b: Which value of Scc is most correct when the flat bar is loaded in tension? (multiple choice)

2. Solve problems 14.4 and 14.12 from your textbook.
   a. Problem 14.4a: Which value of Scc is most correct when the flat bar is loaded in bending? (multiple choice)
   b. Problem 14.4b: Which value of Scc is most correct when the flat bar is loaded in bending? (multiple choice)
   c. Problem 14.4c: Which value of Scc is most correct when the flat bar is loaded in bending? (multiple choice)
   d. Problem 14.12: Compute the maximum principal stress (MPa).
   e. Problem 14.12: Compute the maximum shear stress (MPa).
   f. Problem 14.12: Compute the octahedral shear stress (MPa).

3. Solve problem 14.8 from your textbook.
   a. Determine the maximum tensile stress in the plate (MPa)
   b. Determine the maximum compressive stress in the plate (MPa)

4. Solve problem 15.6 in your textbook.
   a. Determine the magnitude of the axial load P that will cause failure (kN)

5. Solve problem 15.14 in your textbook.
   a. Determine the load P that produces fracture (kN)

Quiz Problem: A plate is made from 17-4 PH steel, given in Table 15.1. The plate contains a through-thickness crack corresponding to Case 1 in Table 15.2. Find the maximum allowable crack size to ensure yielding, not fracture.