Why this study guide exists

This guide is fairly long because it is Prof. Kurtz’s attempt to think of every kind of problem that could possibly be on the exam. This is the complete database and the exam will be very similar to many problems in this guide. This guide exists to encourage students to study very hard, knowing that these are the exact sort of problems to be expected.

This guide is intimidating because of its massive scope and physical size, but the philosophy is that it is far better to be intimidated before the exam in order to become adequately prepared, rather than to be intimidated during the exam due to inadequate preparation.

Exam Format

50 minute time limit. You will be allowed to use your steel manual, a calculator, and pencils. Some questions will be purely conceptual in nature, while others will be computational. Approximately 30% of the exam will be multiple choice, short answer, true/false, etc and these will often be conceptual in nature, while approximately 70% will be fully worked problems.

Coverage

Lesson Objectives from Lessons 1, 2, 3, 4, 5 and Lab 1.

You are expected to be able to do Strength of Materials problems involving direct normal stresses, direct shear stresses, bending normal stresses, beam shear stresses, and the combination of axial and bending effects.

Define strength and serviceability limit states.

1. (1 point) Situation: a structural engineering firm was sued because a building it designed shook so excessively in high winds that the exterior glass fell out, landing in the street. Is this an example of a strength limit state or a serviceability limit state, exceeded? (ANSWER: Serviceability)

2. (1 point) Situation: a hospital sued a structural engineering firm because excessive vibrations in the building were inappropriate for an operating room. Is this an example of a strength limit state or a serviceability limit state, exceeded? (ANSWER: Serviceability)

3. (1 point) Situation: a structural engineering firm was sued because an agricultural building roof it designed collapsed under a record snow loading (more than the region had ever experienced), killing 16 hogs. Is this an example of a strength limit state or a serviceability limit state, exceeded? (ANSWER: Strength)

4. (1 point) TRUE or FALSE. A strength limit state is only considered to have been reached if any parts of the structure (e.g., beams, columns, connections, braces, etc.) fracture. (ANSWER: False)

5. (1 point) TRUE or FALSE. A buckled column is considered an example of a Serviceability Limit State. (ANSWER: False)

Distinguish between strength limit states of material failure and instability.

6. (4 points) Using sketches and descriptions, distinguish between strength limit states of material failure and instability.

Distinguish between member instability (member buckling) and overall structural instability

7. (1 point) TRUE or FALSE. If the loads P were increased until failure occurred, the structure below would fail because the entire structure is unstable. (ANSWER: False)

Indicates pin (or moment-release)

Indicates rigid (or moment-resisting) connection.

Define Structural Analysis and Steel Design.

8. (1 point) TRUE OR FALSE. Structural Analysis is the selection of structural members that have adequate strength and stiffness. (ANSWER: False)

Define Normal and Shear stress, list example occurrences, and state the applicable formulae.

9. (1 point) TRUE or FALSE. The maximum normal stress on this beam is equal to P/A. Given: The beam shown has a cross-sectional area of A.
10. (1 point) TRUE or FALSE. For previous beam, the maximum normal stress on this beam is equal to P/I. (ANSWER: False)

11. (1 point) TRUE or FALSE. For previous beam, the maximum normal stress on this beam is equal to Mc/I, where M=(P/2)(L/2), c = h/2, and I is given. (ANSWER: True)

12. (1 point) True or False. For the previous beam, the average shear stress at the left support is equal to P/(2A). (ANSWER: True)

13. (20 points) Determine the required pin diameter for the pin at point A if it is subjected to double shear and has an allowable shear stress \( \tau_{\text{allow}} = 6 \text{ ksi} \).

Compute internal normal force \( P \), bending moment \( M \), and shear force \( V \), normal stress \( \sigma \), and shear stress \( \tau \) in determinate structures by cutting and applying equilibrium.

14. (20 points). The beam below has a 6”x 6” cross-section. Determine maximum compressive stress due to bending occurring anywhere in the beam and specify the location at which this occurs. Given: Point A is supported by a pin, while Point B is a roller support. (ANSWER: 8.33 ksi at supports, bottom fiber)

15. (20 points). For the previous beam, determine the maximum magnitude of shearing stress that occurs anywhere in the beam and specify the location at which this occurs. (ANSWER: 0.25 ksi at supports, neutral axis)

16. (1 point). TRUE or FALSE. For the previous beam, the internal moment at point A places compression on the top-side of the beam. (ANSWER: False)

17. (20 points). Determine the internal forces and moments at Point B. (ANSWER: V=288 lbs, M = 1152 ft-lb) Given: The beam has a fixed support at Point A and is free at Point C.
18. (1 points) TRUE or FALSE. For the previous beam, the internal moment at point B places compression on the top-side of the beam. (ANSWER: False)

19. (20 points) Determine the magnitude of the internal axial force at point F, specifying either compression or tension as well as the magnitude of the internal moment M at point F, specifying whether the moment causes compression on the top or the bottom of the member. (ANSWER: P=7.5 kips ©, M= 25 ft-kips, © on bottom)

Given: Member ABFC is a continuous member that is connected to member CDE by a pin at C. There are pinned supports at A and E. There is a uniformly-distributed loading of 1 kip/ft from B to C and a uniformly-distributed loading of 2 kips/ft from C to D.

20. (10 points) The steel I-beam (E=29000 ksi) below is made from three 8”x1” plates, resulting in a total depth of 10” and a moment of inertia I = 368 in^4. If the bending stress at the top of the flange is 2.9 ksi, determine the strain at the top of the web (point “a”). (ANSWER: Strain is 0.00008 in/in)
21. (10 points) Determine the internal moment on the section of 10"x10" wooden beam below if the internal normal stress distribution that is shown can be resolved into two internal resultant forces \( R = 1 \text{ kip} \) each. (ANSWER: \( M=6.67 \text{ kip-in} \))

\[ \text{SIDE VIEW OF BENT BEAM} \]

\[ \text{CROSS-SECTION OF WOODEN BEAM} \]

22. (40 points) Determine the resultant normal force on the flange of the Tee beam at section 1-1, located 2 feet to the right of the left support, as shown. Given: The Tee-beam is built from an 8"x1" flange and an 8"x1" web. It is subjected to a 1 kip/ft uniformly distributed load over its 10 foot simple span.

(ANSWER: Resultant on flange is 13.9 kips)

\[ \text{SIDE VIEW OF TEE BEAM} \]

\[ \text{TEE-BEAM CROSS-SECTION} \]

23. (20 points) Determine the normal stress, due to flexure, at point C. Given: the beam is simply-supported by a pin-support at A and a roller support at B. The beam is center-point-loaded by a 100-kip load, as shown. The cross-section is 6"x12", as shown. (ANSWER: Normal stress is 0.579 ksi)

\[ \text{Side View of Beam} \]

\[ \text{Compute} \text{ the moment of inertia of a composite section (such as an I-shape).} \]
\[ \text{(with other objectives)} \]

\[ \text{Compute} \text{ the extreme fiber stress } \sigma \text{ for a member subjected to combined bending and axial effects.} \]

24. (25 points) Determine the required dimension \( b \) of the beam cross section if the allowable bending stress \( \sigma_{\text{allow}} = 1.40 \text{ ksi} \) and the distributed load \( w = 200 \text{ lb/ft} \).

Given: Assume the support at A acts as a pin and that the support at B can be treated as a roller. (ANSWER: \( b=4.02" \))
25. (35 points) Determine the magnitude of normal stress on the top of the beam at point F and specify whether the stress is compressive or tensile. (ANSWER: Max normal stress is 8.125 ksi (tension))

Given: All members have a cross-section that is a 6”x6” solid. Member ABFC is a continuous member that is connected to member CDE by a pin at C. There are pinned supports at A and E. There is a uniformly-distributed loading of 1 kip/ft from B to C and a uniformly-distributed loading of 2 kips/ft from C to D.

26. (5 points) For the frame below, circle the correct answer:
   a. $A_x = 0$ and the axial force in BC is zero.
   b. $A_x \neq 0$ and the axial force in BC is zero.
   c. $A_x = 0$ and the axial force in BC is non-zero.
   d. $A_x \neq 0$ and the axial force in BC is non-zero.

(ANSWER: d)

27. (40 points) A building frame is made with rigidly-connected W8x24 steel shapes, oriented as shown below (note the flange positions). The frame is supported by pinned foundations at points A and E. Positions B and D are rigid connections. There is an internal pin connection at point C. The frame is subjected to a live load of 8 kips at pin C. Determine the maximum compressive stress due to live load at a position that is immediately to the right of Point B and indicate whether this maximum compressive stress occurs on the top or on the bottom side of beam BC. (ANSWER: Max. compressive stress is 46.8 ksi on bottom)
Construct shear and moment diagrams for beams, using the Strength of Materials sign convention.

28. (15 points) Write the function for the internal shear force $V(x)$ and the internal bending moment $M(x)$ of beam AB due to the concentrated moment at B where the origin for $x$ is at pinned support A, directed toward roller support B. Write these functions in terms of $M$, $L$ and $x$.

Given: Concentrated moment $M$ at position $B$.

\[
V(x) = -\frac{M}{L}, \quad M(x) = -\frac{Mx}{L}
\]

29. (30 points) Write the shear function $V(x)$ and the moment function $M(x)$ for the beam shown. It is subjected to a distributed load that increases linearly from 0 at A to 1 kip/ft at B

\[
V(x) = 1.66 - 0.05x^2, \quad M(x)=1.66x - 0.0166x^3
\]

30. (25 points) Draw the moment diagram for the beam below. Label the magnitude and location of each local maximum moment. Given: Support A is a roller, support C is fixed, position B is an internal pin.

\[
\text{(ANSWER: Neg: 46.4 @ C, Pos: 11.1 at 6.93’ left of A. )}
\]

Construct moment diagrams for frames (plotting the diagram on the compression side of the members), computing and labeling min and max points.

31. (30 points) Draw the moment diagram for member BCD only. Use the usual Strength of Materials Convention of plotting the diagram on the compression side of the members. Report all minimum and maximum values.
Compute shear stresses at any position within beams and frames. Illustrate the powerful influences of span length and structural depth on structural stiffness.

32. (10 points). The trussed girder shown was constructed by welding diagonal members to the top and bottom chords such that the distance from the centers of the top and bottom chords is 5”. Under a centerpoint load of P, the given girder was found to deflect 1” at midspan. If the distance from the centers of the two chords was increased to 12”, all other factors staying the same, determine the expected midspan deflection.

(ANSWER: 0.174”)

Illustrate the powerful influence of unbraced length on column buckling.

33. (5 points). Columns A and B have the same cross-section. Column A is 10’-long, while Column B is 6’-long. If Column A buckles elastically at an applied axial force \( P = 100 \) kips, at what force does Column B buckle at, assuming it also buckles elastically?

(ANSWER: 278 kips)

Estimate truss deflections using the moment of inertia of the top and bottom chords, applying beam deflection formulae. Identify real pinned-connection and rigid connections.

34. (2 points) Is the following beam-column connection simple (non-moment-resisting) or rigid (moment resisting) for strong-axis bending?

Given: the wide-flange beam is connected to the column-face with a bolted angle. There is an unconnected space between the beam flange and the face of the column.
Compute the degree of static indeterminacy (DOI) for 2D frames and beams using fundamental principals (Statics), Compute the degree of static indeterminacy (DOI) for 2D frames and beams using the loop method, and/or Compute the degree of static indeterminacy (DOI) for 2D frames and trusses.

Determine the degree of indeterminacy of the structures below (5 points each)

35.

(ANSWER: 1)

36.

(ANSWER: 0)

37.

(ANSWER: 1)

38.

(ANSWER: 6)

39.
45. Show why the structure below is indeterminate, but unstable.
(ANSWER: Put horz force on beam: Sum of forces in x is not zero.)

46. (20 points). Specify the Degree of Indeterminacy of each structure below:

\[
\begin{align*}
\text{DOI} &= \text{__________} \\
\text{DOI} &= \text{__________} \\
\text{DOI} &= \text{__________} \\
\text{DOI} &= \text{__________}
\end{align*}
\]

47. (6 points). Specify whether or not the structure below is stable and justify the answer.
Draw the line diagrams (FBD’s) for a fill beams, girders, columns, and 1'-wide slab strips for a simple (pin-connected) framed building structure, given the dead weights of the structure, Draw moment diagrams from line diagrams, Compute the bending stresses in a beam, given the internal moment and the section properties.

Consider the building below for the following problems. All floors, including the roof consist of 6” thick concrete slabs (concrete unit weight=150 lb/ft³), uniformly-spaced W16x26 fill beams, W18x35 girders, and W12x45 columns. Girders and fills are in strong-axis bending. Slab-strips are considered simply-supported. A typical floor framing plan and 3D image are shown.

48. (3 points) TRUE or FALSE. All of the interior fill beams on the 2nd floor between column line A and B have the same maximum bending moment.
(ANSWER: TRUE)

49. (3 points) TRUE or FALSE. Interior fill beams on the 2nd floor between column line A and B have greater maximum bending moment then interior fill beams on the 3rd floor between column line A and B.
(ANSWER: FALSE)

50. (3 points) TRUE or FALSE. The column at grid location A4 resists a greater axial force at the ground than at a position just above the 3rd floor.
(ANSWER: TRUE)
51. (15 points) Draw the line diagram for fill beam A (see plan view), determine the maximum shear force, the maximum bending moment, and the maximum normal stress due to bending. (ANSWER: V=6.02 kips, M=45.1 kip-ft, σ=14.1 ksi)

52. (25 points) Draw the line diagram for point-loaded girder B (see plan view), determine the maximum shear force, the maximum bending moment, and the maximum normal stress due to bending. (ANSWER: V=28.1 kips, M=252 kip-ft, σ=52.5 ksi)

53. (25 points) Determine the column force for the column at grid location D4 at the foundation level. (ANSWER: 55.8 kips)