

Name _____
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QUIZ 2
Allotted Time: 3 hours

On my honor as a student, I pledge the following:

- I will neither give nor receive unauthorized assistance on this examination.
- During the examination time, I will not refer to written materials other than the exam itself.
- I will neither add nor erase any markings on this examination after the finish time is called.

Signed _____

- In *all* problems, **MAKE YOUR REASONING CLEAR**. Credit is given based on the clarity and correctness of reasoning in the solution process.
- Neglect the self-weight of the structure unless noted otherwise.
- Some problems may include more descriptive data than required to obtain a solution.
- Numbers in square brackets indicate point values.

Here are some meaningful relationships:

CALCULATING ACTUAL STRESS:

bending: $f_b = \frac{M}{S}$

axial: $f_a = \frac{P}{A}$

shear: $f_v = \frac{3}{2} \frac{V}{A}$ (rectangular cross section only)

SECTION PROPERTIES FOR A RECTANGULAR CROSS SECTION:

$$I = \frac{bd^3}{12} \quad S = \frac{I}{c} = \frac{bd^2}{6} \quad A = bd$$

MIDSPAN DEFLECTION OF A SIMPLY-SUPPORTED, UNIFORMLY LOADED BEAM:

$$\Delta = \frac{5wL^4}{384EI} \quad \text{note: } w \text{ denotes the distributed load (e.g. kips per foot)}$$

BUCKLING THEORY:

$$P_{cr} = \frac{\pi^2 EI}{(kL)^2} \quad f_{cr} = \frac{P_{cr}}{A} = \frac{\pi^2 EI}{(kL)^2 A} = \frac{\pi^2 E}{\left(\frac{kL}{r}\right)^2} \quad r = \sqrt{\frac{I}{A}}$$

DESIGN CRITERIA: (actual stress) \leq (allowable stress)

- Bending stress: $f_b \leq F_b$
 - Shear stress: $f_v \leq F_v$
 - Axial stress: $f_a \leq F_a$
- where F_a is the allowable stress in tension or compression.

The allowable compression stress is the smallest of:

- allowable crushing stress F_c
- allowable weak-axis buckling stress F_{cr_y}
- allowable strong-axis buckling stress F_{cr_x}

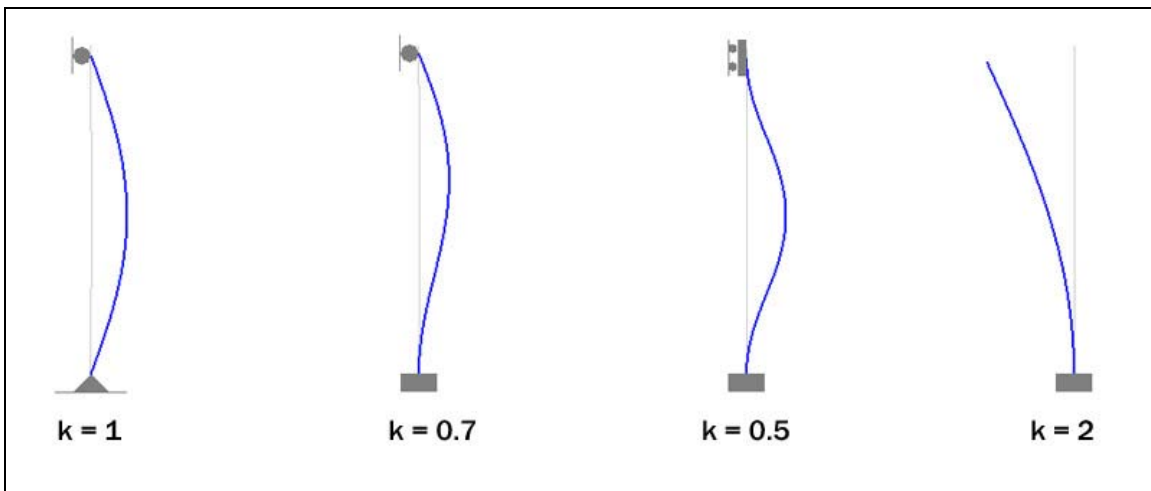
where the allowable buckling stress is:

$$F_{cr} = \frac{f_{cr}}{\text{Factor of Safety}}$$

- Interaction formula for combined bending and axial stress:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1$$

- Effective length factors for various column end conditions:



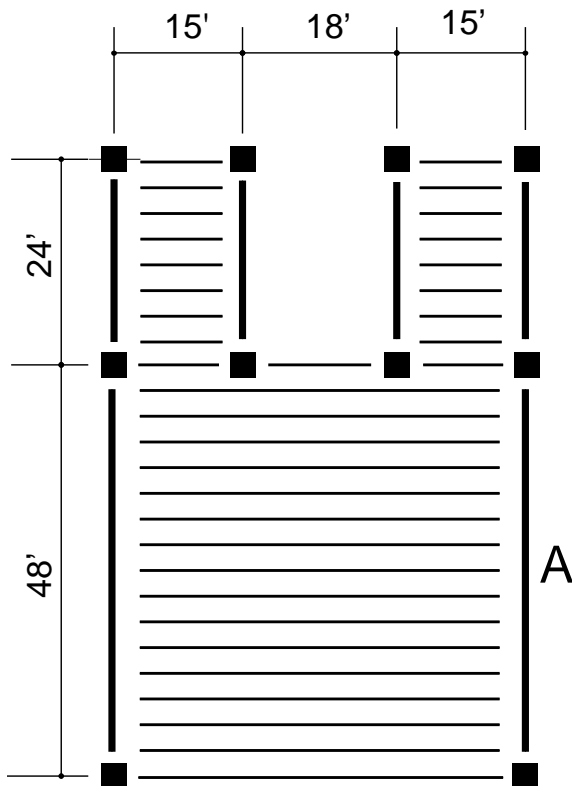
PROBLEM 1 [25] The figure below shows a framing plan for a simple roof structure. The average dead weight of the roof (including joists and beams) is 25 psf and the snow load is 20 psf

Consider the beam labeled *A* on the plan. The beam should be glu-lam timber with the following properties:

$$\begin{aligned} F_b &= 2,400 \text{ psi} \\ F_v &= 165 \text{ psi} \\ E &= 1.8 \times 10^6 \text{ psi} \end{aligned}$$

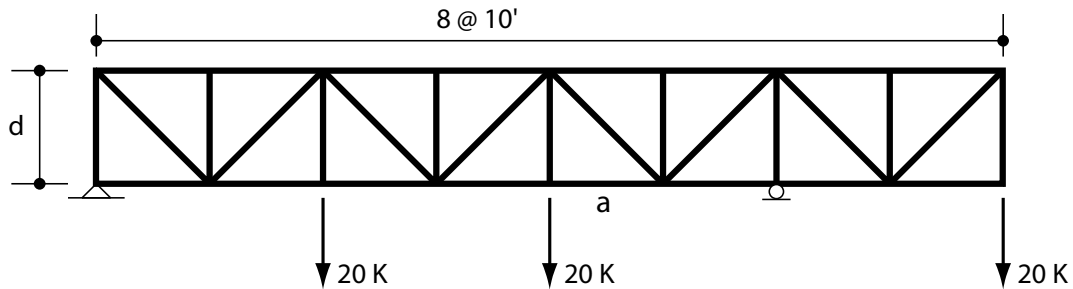
Midspan deflection should not exceed $L/240$.

Determine the lightest glu-lam section that satisfies the given design constraints, assuming that the width of the beam is 5.125 inches. Glu-lams are manufactured in depth increments of 1.5 inches.



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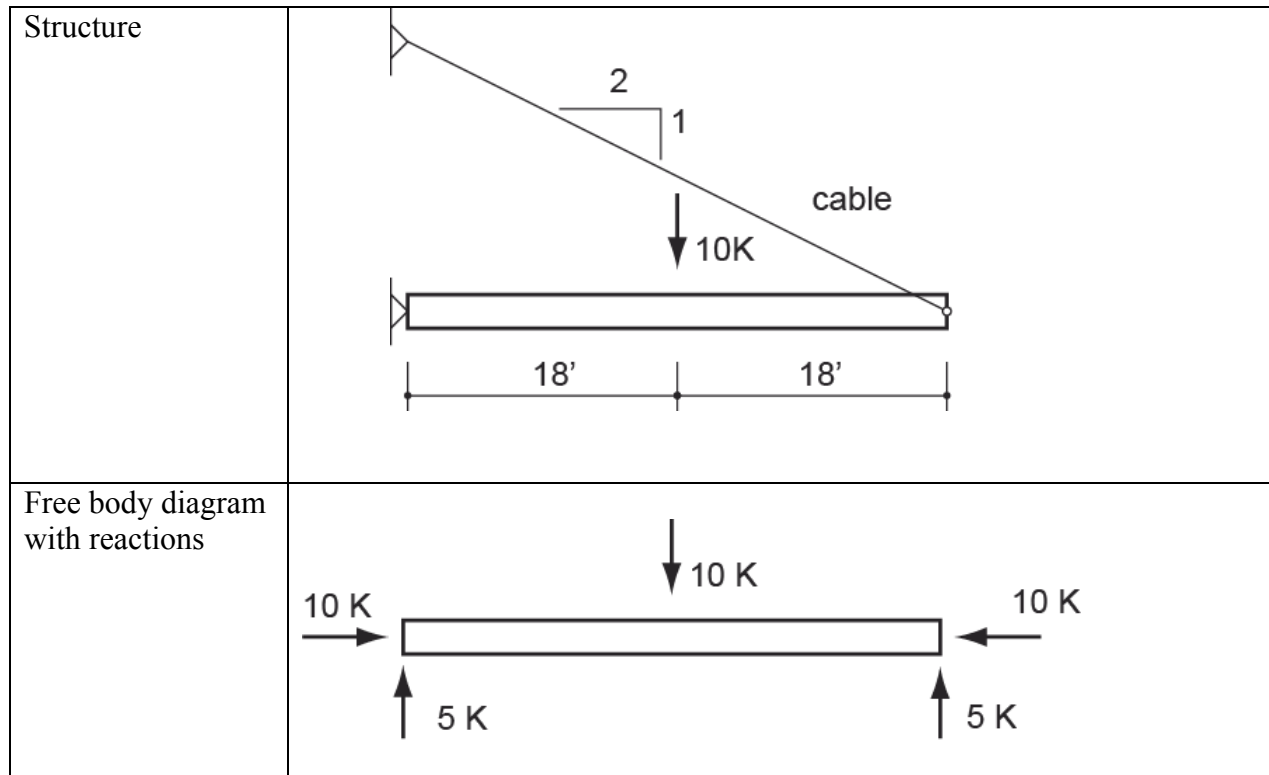
PROBLEM 2: [25] For the truss shown below, do the following:



- Draw a shear diagram for the span and loading condition.
- Draw a moment diagram for the span and loading condition.
- Use the shear diagram to identify the diagonal member(s) with the highest compression force.
- Use the moment diagram to identify the chord member(s) with the highest compression force.
- Assuming one of the design goals is to limit the maximum chord force to 50 kips, use the moment diagram to estimate the minimum dimension “d” required to achieve that goal.
- Assuming the dimension “d” is 10 feet, use a free body diagram and statics to determine the magnitude and sense (i.e. tension or compression) of the force in member “a”.
- On a drawing of the truss, mark zero-force members with an “X”.
- Sketch a configuration of the truss where all of the diagonals are in tension.

[blank]

PROBLEM 3: [25]: The figure below shows a horizontal beam supported by a diagonal cable, along with a free body diagram showing the support reactions.



Assume the following values concerning the section properties and materials:

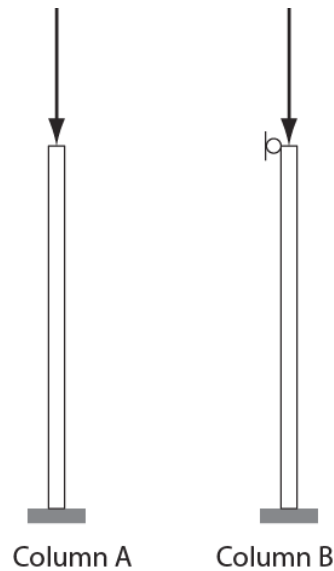
F _b	30 ksi	Allowable bending stress
F _a	10 ksi	Allowable axial stress in compression (assume this has been calculated for you and accounts for buckling).
A	6 in ²	Cross section area of the beam.
S _x	40 in ³	Strong-axis section modulus of the beam (the beam is oriented to bend on strong axis).

Do the following

- Determine the maximum bending moment in the beam.
- Determine the maximum bending stress in the beam.
- Determine the axial stress in the beam.
- Determine whether the beam meets the strength criterion defined by the interaction formula.

[blank]

PROBLEM 4: [10] Consider the two columns shown below.

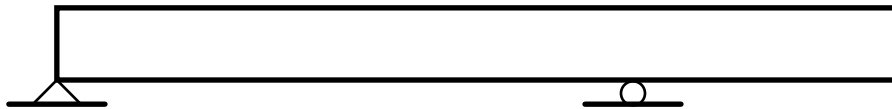


Except for their support conditions, column A and column B have exactly the same structural properties (that is E , I and L). The only difference is that column A is free to move laterally at the top, while the top of column B is braced against lateral movement. Assuming that column A buckles at a load of 100 kips, determine the load which would cause column B to buckle.

PROBLEM 5: Please provide brief answers to the following questions.

- a) [5] Adding reinforcing to the tension side of a reinforced concrete beam always makes the beam stronger, yet design codes limit the amount such reinforcing based on the beam's dimensions. Briefly explain the rationale for this limitation. (Note that the weight of the steel is not significant compared to the concrete).

- b) [5] For the uniformly loaded reinforced concrete beam below, sketch and label the pattern of cracking expected to result from bending moment. In addition, sketch and label the pattern of cracking expected to result from shear. Clearly explain your answer.



- c) [5] Describe and sketch a common mode of failure induced by shear in deep steel girders, and a common strategy for avoiding it.