There are 3 questions with 100 total points possible. Unless told specifically how to solve a problem, you may use any method you wish. Show all work to receive full credit. Mistakes will not be counted against you more than once. If you cannot determine the answer for a problem that is needed for another question, assume a reasonable value and continue. For design problems, if you find that your design is inadequate, do not start over but explain what changes you would make and include sample calculations for any missing steps.

1. A co-worker brings you the design for a 20-foot column, pinned at top and bottom with lateral bracing in the weak direction at mid-height. The factored load, $P_u$, is calculated (correctly) to be 750 kip. The column design calls for a W10×68 section using A992 steel. After some quick calculations you determine that your co-worker has made a mistake and that the W10×68 is not adequate. You see the following calculation: “$KL = 10$ ft; From Table 4–1: $\phi P_n = 768$ kip $> P_u = 750$ kip; use W10×68.”
   (a) (5 points) What was the mistake?
   (b) (5 points) Show that the section is indeed inadequate.
   (c) (5 points) Find the most efficient W10 section that will work.

2. A 12-ft compression member in a truss is constructed from 2L4 × 3\frac{1}{2} × \frac{3}{8} LLBB. Assume the compression member is free to rotate at the ends, the spacing between angles is \frac{3}{8}”, and there is no bracing between end points.
   (a) (3 points) What does “LLBB” stand for?
   (b) (5 points) Look up the member in Table 1–15. Explain why the radius of gyration with respect to the Y-Y axis ($r_y$) is dependent on the spacing, but the X-X axis ($r_x$) has constant radius of gyration regardless of spacing.
   (c) (5 points) Based on the expected loading on the compression member your co-worker has calculated that no intermediate connectors are required. Without any calculations, explain why your co-worker is incorrect and intermediate connectors would indeed be required.
   (d) (7 points) What limit states need to be checked for the compression member? For each limit state, indicate the section of the specification that shows how to calculate the capacity.
   (e) (6 points) Find the compression member in Table 4–9. Based on the numbers given in the table, which of the limit states from part (d) controls? Explain your answer.
   (f) (7 points) Table 4–9 assumes two connectors are used at an effective length of 12 ft. If the number of connectors were increased, would the capacity of the column increase or decrease for the X-X axis? The Y-Y axis? Explain.
3. You are designing the moment frame shown below, which is unbraced. All bending is about the strong axis and buckling about the weak axis can be neglected (assume it does not control the design). Assume all columns buckle simultaneously. All beams use the same section: a W21×93 with a length of \( L_B = 24 \) ft. The columns all have length \( L_C = 12 \) ft. In this problem, you will be designing member EF.

(a) (6 points) In order to get a trial section for member EF, assume a reasonable value for \( K \). Explain your rationale for the \( K \) value you use.

(b) (10 points) Column EF is subject to a factored load, \( P_u \), of 850 kip. Using your value for \( K \) from part (a), pick the most efficient W12 section.

(c) (8 points) Using your trial section from part (b), calculate the correct value for \( K \). Be sure to include the effects of column yielding due to residual stresses (i.e., accounting for the stiffness reduction factor) if applicable. Assume that all columns in the frame will be the W12 you selected in part (b).

(d) (7 points) What is residual stress? How is it caused? Why role does residual stress play in the stiffness reduction factor?

(e) (8 points) Based on the corrected value of \( K \) found in part (c), is your section adequate?

(f) (4 points) For your solution, why is it necessary to assume “all columns buckle simultaneously?”

(g) (4 points) Structurally, how could the building be modified so that the frame would be considered braced?

(h) (5 points) If the frame were braced (e.g., by modifying the structure as indicated in part (g)), would \( K \) increase or decrease? Explain based on basic principles (no equations allowed!).