There are 5 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. 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. (6 points) Three I-sections are used as test specimens under beam loads: a W18×50, a W18×158, and a plate girder with a thin flange. All tests use the same span and unbraced length and all beams are made of the same type of steel. It is found that each beam undergoes a different failure mode. One fails in local buckling, one in lateral-torsional buckling (LTB), and the last by a plastic hinge mechanism. Write the failure mode under the correct section and explain your reasoning.

2. (5 points) Using Table 3–1 in the steel manual, we see that a beam with two point loads laterally braced at the ends and at the load points will have $C_b = 1.00$ for the middle segment. Explain why this is based on the definition of $C_b$.

3. (5 points) Your coworker thinks she has found an error in the steel construction manual. She is looking at a W21×48 in Table 3–2 (page 3–17). The table gives $L_p = 6.09$ feet. However, calculating $L_p$ for a W21×48 as given in the specification (equation F2–5) gives:

$$L_p = 1.76r_y \sqrt{\frac{E}{F_y}} = 1.76(1.66 \text{ in}) \sqrt{\frac{29,000 \text{ksi}}{50 \text{ksi}}} \left(\frac{1 \text{ ft}}{12 \text{ in}}\right) = 5.86 \text{ ft}$$

Your coworker has calculated the equation correctly and there is no error in the table. Why is her value for $L_p$ different from the value given in Table 3–2? Also, why is the value in Table 3–2 larger than the value she calculated—that is, why is it larger and not smaller?
4. For each of the following beams, state the expected flexural failure mode—plastic hinge, lateral torsional buckling (LTB), or local buckling. If the failure is by LTB, is it elastic or inelastic? Reference any charts or tables used. List any assumptions you have to make.

(a) (6 points) A W33 × 130 ($Z_x = 467$ in$^3$) with an unbraced length, $L_b$, of 20 ft.

(b) (6 points) A 24-foot W30 × 108 loaded with a point load at mid-span. Bracing is at the ends and at the point of load as shown below.

(c) (6 points) A W14 × 99 ($Z_x = 173$ in$^3$) supporting a concrete floor slab. Because of shear studs in the W14 × 99, the concrete slab provides continuous lateral bracing.

(d) (6 points) A 19-foot W18 × 55 ($Z_x = 112$ in$^3$) loaded with a constant distributed load and braced at the ends only.
5. The moment diagram below was found from a first-order analysis of a column in a braced frame. Bending is about the strong axis of the column. Bracing in the weak and strong directions occurs at the ends only. The moments shown are already factored. The column is also subject to a factored axial load of \( P_u = 89 \) kip.

-294 kip·ft

\begin{align*}
412 \text{ kip·ft} \\
\end{align*}

(a) (16 points) Determine the lightest W12 section that is adequate for the given loading. Neglect second-order effects and assume \( C_b = 1.0 \).

(b) (4 points) Why are \( P-\delta \) and \( P-\Delta \) referred to as “second order effects?”

(c) (6 points) Using the W12 section found in part (a), compute the magnified moment in the column due to \( P-\delta \) effects. There are no transverse loads.

(d) (4 points) What is meant by the fact that there are no transverse loads?

(e) (4 points) Does your result from part (c) seem reasonable to you? Explain why or why not based on engineering principles.

(f) (4 points) Would \( P-\Delta \) effects be significant in this case? Why or why not?

(g) (6 points) Calculate the value for \( C_b \) for the column.

(h) (4 points) Does your result from part (g) seem reasonable to you? Explain why or why not based on engineering principles.

(i) (12 points) Using your value for \( C_b \) calculated in part (g), determine the lightest W12 that can be used for the column.