There are 5 questions with 100 total points possible. 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.

1. 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) (4 points) W27 × 146 ($Z_x = 464 \text{ in}^3$) with maximum unbraced length ($L_b$) of 10 feet.
   
   (b) (4 points) W33 × 118 ($Z_x = 415 \text{ in}^3$) with $L_b = 14$ feet.
   
   (c) (4 points) W30 × 99 ($Z_x = 312 \text{ in}^3$) with $L_b = 18$ feet and $C_b = 1.14$.
   
   (d) (4 points) W27 × 94 ($Z_x = 278 \text{ in}^3$) with $L_b = 21.5$ feet and $C_b = 1.67$.

2. (24 points) A325 bolts are used for the bearing connection shown below. What is the required size of the bolt using an elastic analysis? Assume the bolts will fail in shear. You do not need to investigate any other failure modes. Check only the bolt you feel will control, explaining why that bolt will control the connection strength.

3. A co-worker brings you the design of a simply supported beam with a single point load at midspan which is braced laterally at the ends and at the point of the load (see below). The beam spans 24 ft. The factored load, $P_u$, at midspan is 55.7 kip. Your co-worker used Table 3-10 in the Steel Construction Manual to design the beam. Here are your co-worker’s calculations:

   
   $$M_u = \frac{P_u L}{4} = \frac{(55.7 \text{ kip})(24 \text{ ft})}{4} = 334 \text{ kip} \cdot \text{ft}$$
   
   $$M'_u = \frac{334 \text{ kip} \cdot \text{ft}}{1.67} = 200 \text{ kip} \cdot \text{ft} \quad M'_u = 200 \text{ kip} \cdot \text{ft}, \quad L_b = 12 \text{ ft} \quad \Rightarrow \quad \text{W16 × 40}$$

   (a) (6 points) Why did your co-worker divide the factored moment by 1.67 to calculate “$M'_u$” in the calculations shown?
(b) (6 points) You quickly realize, however, that the W16 × 40 is **not** adequate for the loading. Why not?

\[ P_u = 55.7 \text{ kip} \]

![Diagram of a column with loads](image)

4. You are designing a column for a building. The column will support a factored load of 880 kip. The column is 30 ft long and is pinned at the top and bottom.

(a) (4 points) What is the lightest W12 or W14 section that can be used for this column?

(b) (8 points) You determine that by using a W12 section you can brace the column in the weak direction at mid-height. Based on this bracing, what is the lightest W12 section that is adequate?

(c) (8 points) If, in addition to the axial load, there is a maximum moment of 190 kip-ft in the beam, how much larger does the section you found in part (a) need to be. Use the same nominal dimension (W12 or W14 as the case may be), just increase the weight to carry the extra moment. Bending is about the strong axis. Neglect moment magnification effects.

(d) (8 points) The moment from part (c) acts at the top of the column. At the bottom of the column the moment is 175 kip-ft, with no transverse loads between the supports. If the moments bend the beam in *single curvature*, will the column found in part (c) still be sufficient? Assume the column is braced against sidesway.

5. (20 points) A bracket must support the service loads shown below. The forces act through the center of gravity of the connection. There are eight A325 bolts, each \( \frac{7}{8} \)-inch in diameter. Considering only the capacity of the bolts, is the connection adequate?

\[ D = 84 \text{ kip} \]
\[ L = 66 \text{ kip} \]

![Diagram of a bracket with loads](image)