Midterm Examination
Duration one hour and fifteen minutes (75 minutes)
Open Book, Notes & Other stuff.
No Neighborly Participation

"The fine print": Notes on the whole examination:

1) The total points on the exam are 120. You are given an extra 20 points to account for computational and inadvertent errors. However your grade will not exceed 100 even if your score is more than 100. If you score 90, you will get a 90. If you score 110 your score will be 100.
2) Numbers in parentheses indicate the tentative grading for each statement.
3) PLEASE BUDGET YOUR TIME. YOU MAY WANT TO ANSWER THE SHORTER OR BEST KNOWN ANSWER QUESTIONS FIRST.

Problem #1: (20 points)
For the cantilever shown in the sketch determine:

a) The deflected shape (5)
b) The moment diagram (5)
c) The shear diagram (5)
d) Show the location of reinforcement if made of reinforced concrete (no details required) (5)

Notes: Show the answer graphically. Use the exam sheet to answer your question. Indicate the critical points. Indicate moments on the tension side and indicate the shear force pair (sign) for orientation.
Problem #2: (40 points)

Determine the design moment capacity $M_{\text{cap}}$ of the T section shown in the figure on the right, if the compression in concrete is at the bottom side of the section.

1. Verify adequacy of placement of reinforcement in section (5)
2. Determine the nominal moment capacity (30)
3. Determine the design moment capacity (5)
4. For 20 extrapolates, determine the moment capacity of same section if the compression was at the top side of the section and the reinforcement would be reversed (the larger amount at the bottom) with 12#8 bars instead of 9#8 in two layers.

Parameters: $f'_c = 4 \text{ ksi}$, $f_y = 60 \text{ ksi}$

Problem #3 (40 points)

Using the same cross section as in Problem #2 with same reinforcement as shown in the figure, determine the size of a concentrated live force (P) - in terms of service load values - which can loaded at the end of the cantilever if the dead load component of the design load is assumed to be 30% and the reinforcement arrangement:

Required:
1. Show the approximate moment diagram and calculate the value of the concentrated force (10)
2. Show the correct arrangement of the cross section in a proper sketch (20)
3. Show the reinforcement along the beam. Indicate approximately how much of the reinforcement can be reduced at the mid length of the beam (10)

[If you did not calculate the moment in Problem #2 you may use 1200 k-ft for the design moment – for a deduction of 5 points from this problem]

Problem #4 (20 points)

For same cross section and the same beam as in Problem #3, determine the shear reinforcement in the critical section near the application of the concentrated load. [Assume that the only contributor to the shear demand in the critical section is the live load]. Show cross section with suggested reinforcement.
Section works like a rectangular shape, 16 x 30, doubly reinforced.

1. The placement of reinforcement of \( \text{GHD} \) in \( \text{H}^2 \) is by "bias" from notes. 

2. GHD are at 16" for 3 1/4" aggregates, 36. 

3. No problem placing the GHD here in a 12" wide flange. 

4. Area: 
   \[ A_{\text{ty}} = A_0 + 3 \times 30 \times 16 = 711 \text{ in}^2 \]
   \[ A_{\text{ty}}' = 3.51 \text{ in}^2 \]
   \[ A_0 = A_{\text{ty}} - A_{\text{ty}}' = 3.51 \text{ in}^2 \]

5. 
   \[ f_{\text{c}2} = \frac{3.51 \times 60}{16 \times 30 \times 0.95 \times 12} = 0.114 \]

6. 
   \[ f_{\text{ty}} = 2(3.51 \times 60 + 3.51 \times 60 + 34(1 - 0.114/2) = 13664 \text{ k-} \text{m} = 1153 \text{ k-} \text{f} \]

7. 
   \[ f_{\text{ty}}' = 293.7 \]

8. <may check if negative reinforcement yield>

9. 
   \[ M_d = 0.9 \times 1153 = 1038 \text{ k-} \text{f} \]

[Diagram of section]

10. 
    \[ A_0 = 12.64, A_0' = 3.50 \]

11. 
    \[ M_0 = 10258 \text{ k-} \text{m} \]

12. 
    \[ A_{\text{ty}} = A_{\text{ty}} - A_{\text{ty}}' = 12.64 - 562 = 7.12 \text{ in}^2 \]

13. 
    \[ M_0 = 3.60 \times 7.12 - d \left( A_0 - A_0' \right) \]

14. 
    \[ M_0 = 7.12 - 15.60 = 3.52 \]

15. 
    \[ M_0 = 3.62 \times 16 \times 33 \times 0.126 = 6696 \text{ k-} \text{f} \]

16. 
    \[ M_0 = 6531 \text{ k-} \text{f} \]

17. 
    \[ M_d = 0.9 \times 1761 = 1585 \text{ k-} \text{f} \]
Problem 4.3

1. See sketch
   \[ M_1 = 1200 \text{ ft-lb} \]
   \[ M_2 = 0.75 \times 1200 = 900 \text{ ft-lb} \]
   \[ P = \frac{112}{1.7 \times 3} = 840 \text{ kips} \]
   \[ W = 982 \text{ kips} \]

2. The moment produces tension at the top, therefore the cross section with the flanges at top and web at bottom for the positive condition for this problem.

3. More efficient arrangement is obtained when section is reinforced like in 2d) with flanges at bottom.

4. The reinforcement arrangement:
   
   Beam:
   \[ M = \frac{840}{4} + \frac{360}{4} = 510 \text{ k-ft} \]
   \[ Mu = 510 \times 0.9 = 567 \text{ k-ft} \]
   \[ Mu = 1200 \times 0.9 = 1080 \text{ k-ft} \]

   Compressive reinforcement share is \( \frac{567}{1332} \approx 0.42 \text{ of total} \)

   Tensile reinforcement needed = \( \frac{567 \times 9}{667} = 7.56 \approx 8 \times \frac{1}{4} \text{ in.} \)

   Therefore, one can remove all compressive reinforcement (6#8) and use tension rod (1#8). (See sketch above.)
Problem #4

Critical section is at a distance 33" from 1st point
and at 2'-8". (see sketch)

Shear force for shear force in critical section I:

\[ \frac{V_f}{3} = \frac{99 \times 1000}{33 \times 16 \times 0.85} = 221 \text{ psi} \]

\[ V_f = 2 \times 221 = 442 \text{ psi} \]

\[ V_{req} = 95 \text{ psi} \]

Choose #3.26" closed stirrups [n=2] (allow by code here)

\[ f_s = \frac{W_{sec}}{A_{stir}} = 2 \times 0.11 \times 60 \times 10^3}{6 \times 33} = 60 \text{ psi} < 95 \text{ psi} \]

Therefore shear reinforcement can be 2 #3.26" stirrups.

\[ f_{stirr} = \frac{4 \times 0.11 \times 60 \times 10^3}{6 \times 33} = 139 \text{ psi} > 95 \text{ psi} \text{ (required)} \]

May refine this to #3.26" stirrups.