Section:  
Name:  
Key

Student Number:  

"Aggies do not lie, cheat, or steal, nor do they tolerate those who do." – Aggie Code of Honor

By my signature below I pledge that my conduct on this exam is consistent in every way with the Aggie Code of Honor:

Signature:  

1. This exam consists of Six (6) problems that are equally weighted
2. Some problems have multiple parts.
3. Be sure to carefully read and properly analyze each question that is asked. Do not jump to unfounded conclusions, but also do not overlook or oversimplify problems either.
4. Be sure to show all work, including sketches, Free Body Diagrams, and calculations, and organize your solution procedure as clearly and systematically as possible.
5. Work problems in the space provided on the exam sheets.
6. Work efficiently, neatly, and use pencil.
7. Clearly indicate final answers by enclosing in a "box" or place answer in box if box is provided. Include any and all appropriate units.

Problem 1: ______ / 10
Problem 2: ______ / 10
Problem 3: ______ / 10
Problem 4: ______ / 10
Problem 5: ______ / 10

TOTAL: ______ / 50
Problem 1. Determine the minimum required diameter, D, of a solid steel shaft that is required to transmit 100 hp while rotating at a constant rate of 1200 rpm. In addition, calculate the relative angle of twist, ϕ, between the two ends of the shaft assuming that the shaft is 5 ft in length. Assume that the maximum allowable shearing stress is 7,500 psi and that $G = 11.2 \times 10^6$ psi. Enter your answers in the blanks provided. Show all work to receive full credit.

\[
P = \left( \frac{100 \text{ hp}}{550 \text{ ft}-\text{lb/s}} \right) \left( \frac{12 \text{ in}}{\text{ft}} \right) = 660,000 \text{ in-lb/s}
\]

\[
W = \left( \frac{1200 \text{ rpm}}{2\pi \text{ rad/rev}} \right) \left( \frac{1}{60 \text{ min}} \right) = 125.7 \text{ rad/s}
\]

\[
P = TW
\]

\[
T = \frac{P}{W} = \frac{660,000}{125.7} = 5,250.6 \text{ in-lb/s}
\]

\[
J = \frac{7\pi}{2} r^4 = 1.5708 r^4
\]

\[
r = \frac{T r}{J}
\]

\[
7500 \text{ psi} = \frac{5250.6 \text{ in-lb/s}}{1.5708 r^4}
\]

\[
r^3 = \frac{5250.6}{7500} \left( \frac{1}{1.5708} \right)
\]

\[
r = 1.4457
\]

\[
r = 1.7639
\]

\[
d = 2r = 1.528 \text{ in}
\]

\[
D = 1.528 \text{ in} \quad \text{and} \quad \phi = 0.0526 \text{ rad}
\]
Problem 2. Draw complete shear and moment diagrams for the beam loaded as shown. Write the shear and bending moment equations for section BC.

\[ \sum M_A = 0 \]

\[-1500(5) - 2500(15) + 1000 + Dy = 0 \]

\[ Dy = 2200 \]

\[ \sum F_y = 0 \]

\[ A_y - 1500 - 2500 + 2200 = 0 \]

\[ A_y = 1000 \]
\[ \sum F_y = 0 \]
\[ 1800 - 1500 - V_{BC} = 0 \]
\[ V_{BC} = 300 \]

\[ \sum M_{cut} = 0 \]
\[ M_{BC} + 1500(x-5) + 1000 - 1800x = 0 \]
\[ M_{BC} + 1500x - 7500 + 1000 - 1800x = 0 \]
\[ M_{BC} = 300x + 6500 \]

\[ x = 5 \Rightarrow 10 \]
Problem 3. A 6 x 10 in. timber beam has been strengthened by attaching a steel plate to the bottom of the cross-section as shown. The beam is subjected to a positive moment of 200 in-k about its horizontal axis. Calculate the magnitudes of the maximum normal stresses, \( \sigma_{\text{wood}} \) and \( \sigma_{\text{steel}} \), acting in the wood and the steel. Assume that \( E_{\text{wood}} = 1.5 \times 10^6 \) psi and \( E_{\text{steel}} = 30 \times 10^6 \) psi. Enter your answers in the blanks provided. Show all work to receive full credit.

\[
\sigma_{\text{wood}} = \frac{F_{\text{wood}}}{A_{\text{wood}}} = \frac{30 \times 10^6}{1.5 \times 10^6} = 20
\]

\[
\sigma_{\text{steel}} = \frac{F_{\text{steel}}}{A_{\text{steel}}} = \frac{7354}{7.14} = 1000
\]

\[
\bar{y} = \frac{(6)(10)(5.5) + 100(.5)(.5)}{12(10) + 100(.5)} = 3.114
\]

\[
I = \frac{1}{12} (6)(10)^3 + [6](10)(5.5 - 3.14)^2 + \frac{1}{12} (100)(.5)^3 + (100)(.5)(5.5 - 3.14)^2
\]

\[
I = 500 + 341.6 + 1.04 + 284.6 = 1127.8 \text{ in}^4
\]

\[
\sigma_{\text{wood}} = 1300.5 \text{ psi} \quad \text{and} \quad \sigma_{\text{steel}} = 11050.4 \text{ psi}
\]
\[ T_{\text{wood}} = \frac{(200,000)(7.386)}{1127.2} \]

\[ T_{\text{wood}} = \frac{1310.5}{1} \quad \text{ps: c} \]

\[ T_{\text{steel}} = \frac{20 (200,000)(3.14)}{1127.2} \]

\[ T_{\text{steel}} = 11,050.4 \quad \text{ps: } T \]
Problem 4. Beam AB is made of three wood planks that are glued together along joints \(a\) and \(b\) as shown. The beam is subjected to the loading shown. The width of each glued joint is 20 mm as shown. The location of the centroid of the cross-section is 68.3 mm above the base of the cross-section as shown. Determine the shearing stress, \(T_a\) and \(T_b\) in joints \(a\) and \(b\) and calculate the maximum shearing stress, \(T_{\text{max}}\) in the cross-section located at section \(n-n\). Enter your answers in the blanks provided. Show all work to receive full credit.

\[
V_{nn} = \frac{1.5 \times 10^4}{2} \\
I = \frac{1}{12} (100)(20)^3 + (10)(20)(110-68.3) \\
+ \frac{1}{2} (20)(20)^3 + (20)(20)(60-68.3) \\
+ \frac{1}{2} (60)(20)^3 + (60)(20)(68.3-10) \\
I = 6.667 \times 10^6 + 3.826 \times 10^5 \\
+ 8.533 \times 10^5 + 1.102 \times 10^5 \\
+ 4.000 \times 10^5 + 4.679 \times 10^5 \\
I = 8.975 \times 10^6 \text{ mm}^4 \\
\text{or} \\
8.975 \times 10^6 \text{ m}^4 \\

T_a = \frac{V_{\Phi}}{I_b} = \frac{(1.5 \times 10^4)(8.34 \times 10^{-3})}{(8.975 \times 10^6) \times 0.20} \\
T_a = 6.969 \times 10^5 \text{ N/m}^2 \\
T_b = 2.923 \times 10^5 \text{ N/m}^2 \quad T_{\text{max}} = 7.809 \times 10^5 \text{ N/m}^2
\[ Q_d = (60)(10)(582) = 3.498 \times 10^4 	ext{ mm}^3 \]

or
\[ 3.498 \times 10^{-5} \text{ m}^3 \]

\[ T_d = \left( \frac{1500 (3.418 \times 10^{-5})}{8.975 \times 10^{-6}} \right) \cdot 0.025 \]

\[ T_d = 2.923 \times 10^5 \frac{N}{m^2} \]

\[ Q_{\text{max}} = (100)(20)(41.7) + (20)(31.7) \left( \frac{31.7}{2} \right) \]

\[ Q_{\text{max}} = 8.340 \times 10^4 + 1.005 \times 10^4 \]

\[ Q_{\text{max}} = 9.345 \times 10^4 \text{ mm}^3 \text{ or } 9.345 \times 10^{-5} \text{ m}^3 \]

\[ T_{\text{max}} = \frac{1500 (9.345 \times 10^{-5})}{(8.975 \times 10^{-6}) \cdot 0.025} \]

\[ T_{\text{max}} = 7.899 \times 10^5 \frac{N}{m^2} \]