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"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this exam."

______________________________
Signature of student

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### Table 5-1 Centroid Locations for a Few Common Line Segments and Areas

<table>
<thead>
<tr>
<th>Segment</th>
<th>Formula for Length</th>
<th>Formula for Centroid</th>
<th>Formula for Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular arc</td>
<td>$L = 2\pi \alpha$</td>
<td>$x_c = \frac{r \sin \alpha}{\alpha}$</td>
<td>$A = \pi r^2 \alpha$</td>
</tr>
<tr>
<td></td>
<td>$x_c = 0$</td>
<td>$y_c = 0$</td>
<td></td>
</tr>
<tr>
<td>Quarter circular arc</td>
<td>$L = \frac{\pi r}{2}$</td>
<td>$x_c = \frac{2r}{\pi}$</td>
<td>$A = \frac{\pi r^2}{4}$</td>
</tr>
<tr>
<td></td>
<td>$y_c = \frac{2r}{\pi}$</td>
<td>$x_c = 4r$</td>
<td>$y_c = \frac{4r}{3\pi}$</td>
</tr>
<tr>
<td>Semicircular arc</td>
<td>$L = \pi r$</td>
<td>$x_c = r$</td>
<td>$A = \frac{\pi r^2}{2}$</td>
</tr>
<tr>
<td></td>
<td>$y_c = \frac{2r}{\pi}$</td>
<td>$y_c = \frac{4r}{3\pi}$</td>
<td></td>
</tr>
<tr>
<td>Rectangular area</td>
<td>$A = bh$</td>
<td>$x_c = \frac{b}{2}$</td>
<td>$A = \frac{mb}{4}$</td>
</tr>
<tr>
<td></td>
<td>$y_c = \frac{h}{2}$</td>
<td>$x_c = \frac{4a}{3\pi}$</td>
<td>$y_c = \frac{4b}{3\pi}$</td>
</tr>
<tr>
<td>Triangular area</td>
<td>$A = \frac{bh}{2}$</td>
<td>$x_c = \frac{2b}{3}$</td>
<td>$A = \frac{bh}{3}$</td>
</tr>
<tr>
<td></td>
<td>$y_c = \frac{h}{3}$</td>
<td>$x_c = \frac{3b}{4}$</td>
<td>$y_c = \frac{2h}{10}$</td>
</tr>
<tr>
<td>Triangular area</td>
<td>$A = \frac{bh}{2}$</td>
<td>$x_c = \frac{a + b}{3}$</td>
<td>$A = \frac{2bh}{3}$</td>
</tr>
<tr>
<td></td>
<td>$y_c = \frac{h}{3}$</td>
<td>$x_c = \frac{5b}{8}$</td>
<td>$y_c = \frac{2h}{5}$</td>
</tr>
</tbody>
</table>
Problem 1) Locate the centroid (neutral x-x axis) for the shape shown below. Use y1=2", y2=6", y3=10", y4=3", y5=2", x1=x3=2", x2=6".

\[ \bar{x} = 5 \text{ by symmetry} \]

Rectangle centroid: \( \bar{y} = \left( \frac{2+3+10+6+2}{2} \right) = \left( \frac{23}{2} \right) = 11.5 \)

Circle centroid: \( \bar{y} = \left( 2+3+10+\frac{\pi}{2} \right) = (15+\frac{\pi}{2}) = 18 \)

Semicircle centroid: \( \bar{y} = \left( 2 + \frac{\frac{\pi}{2}}{3\pi} \right) = \left( 2 + \frac{\frac{\pi}{6}}{3\pi} \right) = \left( 2 + \frac{\pi}{18} \right) = 3.27 \)

A rectangle = \((10)(23) = 230 \)
A circle = \(- (\pi r^2) = -9\pi = 28.27 \)
A semicircle = \(- (\pi r^2) = -4.5\pi = 14.14 \)

\[ \bar{y} = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3} = \frac{(230)(\frac{23}{2}) - (9\pi)(18) - (4.5\pi)(2 + \frac{\pi}{2})}{230 - 9\pi - 4.5\pi} \]

\[ \bar{y} = \frac{2089.79}{187.59} = 11.41 \]

\[
\text{centroid} = (5, 11.41) \\
\text{neutral axis } x = 11.14
\]
Problem 2) Solve for the reactions for the structure loaded as shown. Note – nothing on the drawing is to scale for your numbers. The distributed load shown is elliptical, and \( w = 2 \text{kN/m} \). \( M = 50 \text{kNm} \), \( x_1 = 6 \text{m} \), \( x_2 = 5 \text{m} \), \( x_3 = 4 \text{m} \).

\[
P = \frac{\pi (6 \text{m}) (2 \text{kN/m})}{4} = 9.425 \text{kN}
\]

\[
x_4 = \frac{4a}{3\pi} = \frac{4(6\text{m})}{3\pi} = 2.546 \text{m}
\]

\[
x_5 = 6\text{m} - 2.546 \text{m} = 3.454 \text{m}
\]

\[
y_j = \tan 50^\circ \quad \Rightarrow \quad y_j = x_2 \tan 50^\circ
\]

\[
x_2 = 5\tan 50^\circ = 5.959 \text{m}
\]

\[
\Sigma M_A = 0 = (9.425 \text{k})(3.454 \text{m} + 9 \text{m}) + 50 - R_{BH}(5.959 \text{m})
\]

\[
R_{BH} = 28.09 \text{kN}
\]

\[
\Sigma F_H = 0 = A_H - 28.09 \text{kN}
\]

\[
A_H = 28.09 \text{kN}
\]

\[
\Sigma F_V = 0 = -9.425 + A_V
\]

\[
A_V = 9.425 \text{kN}
\]
Problem 3) Solve for the volume generated by rotating the shape shown about the y-y axis, and the total surface area generated. In other words, solve for the total volume of the shape so I can buy enough steel to make it, and solve for the surface area so I can buy enough paint to paint it. Use x1 = 6", x2 = 5" and x3=4", y1=8", y2=3."

\[ A_1 = 8(5) = 40 \text{ in}^2 \]

\[ y_{C1} = 8 + \frac{5}{2} = 8.5 \text{ in} \]

\[ V_1 = 40(2\pi(8.5)) = 680\pi \]

\[ A_2 = \frac{1}{2}(5)(3) = 7.5 \text{ in}^2 \]

\[ y_{C2} = 6 + \left(\frac{9+5}{3}\right) = 10.67 \text{ in} \]

\[ V_2 = 7.5(2\pi(10.67)) = 160\pi \]

\[ V_{total} = 680\pi + 160\pi = 840\pi \Rightarrow V_{total} = 2638.94 \text{ in}^3 \]

\[ SA_1 = 8(2\pi)(6) + 8(2\pi)(11) + 5(2\pi)(6 + \frac{5}{2}) + \sqrt{9^2 + 3^2}(2\pi)(6 + \frac{9}{2}) + \]

\[ + \sqrt{9^2 + 3^2}(2\pi)(11 + \frac{4}{2}) = 301.6 + 557.92 + 207.04 + 1625.88 + 408.41 \]

\[ SA_{total} = 2155.85 \text{ in}^2 \]

\[ \text{Good.} \]
Problem 4) A set of forces has been determined to cause a total moment about point B equal to 100i - 200j + 400k. Determine the scalar component of the moment about the CB axis.

\[
\begin{align*}
\vec{e} &= \frac{7\hat{i} - 4\hat{j} - 5\hat{k}}{\sqrt{7^2 + (-4)^2 + (-5)^2}} = \frac{7\hat{i} - 4\hat{j} - 5\hat{k}}{9.487} \\
&= +0.738\hat{i} - 0.422\hat{j} - 0.527\hat{k}
\end{align*}
\]

\[
|M| = \vec{M} \cdot \vec{e}
\begin{align*}
&= \left[100\hat{i} - 200\hat{j} + 400\hat{k}\right] \cdot \left[0.738\hat{i} - 0.422\hat{j} - 0.527\hat{k}\right] \\
&= -52.6
\end{align*}
\]
Problem 5) Determine the vertical and horizontal components for the reaction at C. The bar has a total mass of 500kg, and x1 = 2m, x2 = 10m, x3 = 4m.

\[ \Sigma M_C = 0 = \frac{12}{13}T(14) + 4905(8) - \frac{3}{5}T(4m) \]

\[ = -12.92T + 39240 - 2.4T \]

\[ 15.32T = 39240 \]

\[ T = 2561 \text{ N} \]

\[ \Sigma F_v = 0 = \frac{12}{13}(2561) - 4905 + \frac{3}{5}(2561) + C_v \]

\[ C_v = 4905 - 2364 - 1537 \]

\[ = 1004 \text{ N} \]

\[ \Sigma F_h = 0 = \frac{5}{13}(2561) - \frac{4}{5}(2561) + C_h \]

\[ C_h = 1064 \text{ N} \]
Problem 6) Determine the load P required to lift the uniform load w = 200 #/ft. Use x1 = 4 ft, x2 = 6 ft.

\[ \Sigma M_A = 0 = 4P(4) + P(8) + P(12) - 1200(21) \]

\[ P = 700 \]
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### Table 5-1: Centroid Locations for a Few Common Line Segments and Areas

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<thead>
<tr>
<th>Shape</th>
<th>Formula</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular arc</td>
<td>$L = 2r\alpha$</td>
<td><img src="image" alt="Circular arc" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{r \sin \alpha}{\alpha}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = 0$</td>
<td></td>
</tr>
<tr>
<td>Circular sector</td>
<td>$A = r^2\alpha$</td>
<td><img src="image" alt="Circular sector" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{2r \sin \alpha}{3\alpha}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = 0$</td>
<td></td>
</tr>
<tr>
<td>Quarter circular arc</td>
<td>$L = \frac{\pi r}{2}$</td>
<td><img src="image" alt="Quarter circular arc" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{2r}{\pi}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{2r}{\pi}$</td>
<td></td>
</tr>
<tr>
<td>Quadrant of a circle</td>
<td>$A = \frac{\pi r^2}{4}$</td>
<td><img src="image" alt="Quadrant of a circle" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{4r}{3\pi}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{4r}{3\pi}$</td>
<td></td>
</tr>
<tr>
<td>Semicircular arc</td>
<td>$L = \pi r$</td>
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</tr>
<tr>
<td></td>
<td>$x_C = r$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{2r}{\pi}$</td>
<td></td>
</tr>
<tr>
<td>Semicircular area</td>
<td>$A = \frac{\pi r^2}{2}$</td>
<td><img src="image" alt="Semicircular area" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = r$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{4r}{3\pi}$</td>
<td></td>
</tr>
<tr>
<td>Rectangular area</td>
<td>$A = bh$</td>
<td><img src="image" alt="Rectangular area" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{b}{2}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{h}{2}$</td>
<td></td>
</tr>
<tr>
<td>Quadrant of an ellipse</td>
<td>$A = \frac{\pi ab}{4}$</td>
<td><img src="image" alt="Quadrant of an ellipse" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{4a}{3\pi}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{4b}{3\pi}$</td>
<td></td>
</tr>
<tr>
<td>Triangular area</td>
<td>$A = \frac{bh}{2}$</td>
<td><img src="image" alt="Triangular area" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{2b}{3}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{h}{3}$</td>
<td></td>
</tr>
<tr>
<td>Parabolic spandrel</td>
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<td><img src="image" alt="Parabolic spandrel" /></td>
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<tr>
<td></td>
<td>$x_C = \frac{3b}{4}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{3h}{10}$</td>
<td></td>
</tr>
<tr>
<td>Triangular area</td>
<td>$A = \frac{bh}{2}$</td>
<td><img src="image" alt="Triangular area" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{a + b}{3}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{h}{3}$</td>
<td></td>
</tr>
<tr>
<td>Quadrant of a parabola</td>
<td>$A = \frac{2bh}{3}$</td>
<td><img src="image" alt="Quadrant of a parabola" /></td>
</tr>
<tr>
<td></td>
<td>$x_C = \frac{5b}{8}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$y_C = \frac{2h}{5}$</td>
<td></td>
</tr>
</tbody>
</table>
Problem 1) Determine the load $P$ required to lift the uniform load $w = 400 \#$/ft. Use $x_1 = 6$ ft, $x_2 = 10$ ft.

\[ \sum M_B = 0 = 2400 \#(31') - 4P(22') - P(16') - P(10') \]

\[ 114P = 77400 \]

\[ P = 653 \# \]
Problem 2) Locate the centroid (neutral x-x- axis) for the shape shown below. Use $y_1=4''$, $y_2=12''$, $y_3=15''$, $y_4=6''$, $y_5=4''$, $x_1=x_3=4''$, $x_2=12''$.

\[ A_1 = 820 \text{ in}^2 \]
\[ A_2 = -113 \]
\[ A_3 = -56.6 \]

\[ \Sigma M_{REF} = (41')(20') \left[ 4\frac{1}{2}'' \right] - \frac{\pi(12'')^2}{4} \left[ 3'1'' \right] - \frac{\pi(12'')^2}{8} \left[ 10'' - \frac{4(6'')}{3\pi} \right] \]

\[ \Sigma M_{REF} = \left[ (41)(20) - \frac{\pi(12)^2}{4} - \frac{\pi(12)^2}{8} \right] y_i \]

\[ \bar{y} = 19.81 \text{ in} \]
Problem 3) Solve for the volume generated by rotating the shape shown about the y-y axis, and the total surface area generated. In other words, I want the total volume of the shape so I can buy enough steel to make it, and the surface area so I can buy enough paint to paint it. Use \( x_1 = 4" \), \( x_2 = 3" \), \( x_3 = 2" \), \( y_1 = 6" \), \( y_2 = 3" \).

\[
L_2 = \sqrt{3^2 + 3^2} = 4.24\text{ in} \quad g_2 = \frac{2'' + 3''}{2} = 3.5''
\]

\[
L_2 = \sqrt{3^2 + 3^2} = 4.24\text{ in} \quad g_2 = \frac{2'' + 3''}{2} = 3.5''
\]

\[
L_1 = \sqrt{7^2 + 3^2} = 7.616\text{ in} \quad g_1 = \frac{2'' + 9''}{2} = 5.5''
\]

\[
L_3 = 6'' \quad g_3 = 9''
\]

\[
L_4 = 6'' \quad g_4 = 5''
\]

\[
L_5 = 4'' \quad g_5 = 7''
\]

\[
A_1 = \frac{1}{2} \times 9 \times 6 = 27\text{ in}^2
\]

\[
A_2 = 9 \times 6 = 54\text{ in}^2
\]

\[
V = A_1 \times (2\pi \times 4) + A_2 \times (2\pi \times 2) = 6\text{ in}^2 \times (2\pi \times 5.33) + 54\text{ in}^2 \times 2\pi \times 7''
\]

\[
V = 256\text{ in}^3
\]

\[
S_1 = L_1(2\pi g_1) = 7.616\text{ in} \times (2\pi) \times (5.5'') = 263
\]

\[
S_2 = L_2(2\pi g_2) = 4.24\text{ in} \times (2\pi) \times (3.5'') = 93
\]

\[
S_3 = L_3(2\pi g_3) = 6'' \times (2\pi) \times (9'') = 339
\]

\[
S_4 = 6'' \times (2\pi) \times (5'') = 188
\]

\[
S_5 = 4'' \times (2\pi) \times (7'') = 176
\]

\[
1060\text{ in}^2
\]
Problem 4) Determine the vertical and horizontal components for the reaction at C. The bar has a total mass of 100 kg. Use \( x_1 = 3 \text{m}, x_2 = 8 \text{m}, x_3 = 10 \text{m} \).

\[
W_{\text{bar}} = 100 \text{kg}(9.81 \text{m/s}^2) = 981 \text{ N @ center}
\]

\[
\Sigma M_c = 0 = \frac{12}{13} T(18 \text{m}) - \frac{4}{5} T(10 \text{m}) + (981 \text{N})(\frac{21}{2} \text{m})
\]

\[
16.62T + 8T = 10300
\]

\[
T = 418 \text{ N}
\]

\[
\Sigma F_H = 0 = \frac{5}{13} (T) - \frac{3}{5} (T) + C_H
\]

\[
C_H = \frac{5}{13} (418) + \frac{3}{5} (418) = 90 \text{ N}
\]

\[
\Sigma F_V = 0 = \frac{12}{13} T + \frac{4}{5} T - 981 + C_V
\]

\[
C_V = 981 - \frac{12}{13}(418) - \frac{4}{5}(418)
\]

\[
= 261 \text{ N}
\]
Problem 5) Solve for the reactions for the structure loaded as shown. Note – nothing on the drawing is to scale for your numbers. The distributed load shown is parabolic with \( w = 2 \text{k/ft} \), and \( M = 200 \text{kft} \), \( x_1 = 10 \text{ft} \), \( x_2 = 8 \text{ft} \), \( x_3 = 6 \text{ft} \).

\[
\omega \quad P = \frac{2bh^3}{3} = 2(10 \text{ft})(2 \text{k/ft}) = 13.33 \text{k}
\]

\[
M = 200 \text{kft}
\]

\[
y = 8 \tan 60^\circ = 13.86 \text{ft}
\]

\[
\tan 60^\circ = \frac{y}{8}
\]

\[
\Sigma M_A = 0 = (13.33 \text{k})(6.25+8+6) - 200 - R_c(13.86 \text{ ft})
\]

\[
R_c = 5.05 \text{k}
\]

\[
\Sigma F_v = 0 = -13.33 \text{k} + A_v
\]

\[
A_v = 13.33 \text{k}
\]

\[
\Sigma F_h = 0 = -5.05 \text{k} + A_h
\]

\[
A_h = 5.05 \text{k}
\]
Problem 6) A set of forces causes a total moment about point B equal to \(-100\mathbf{i} + 200\mathbf{j} + 600\mathbf{k}\). Determine the scalar component of the moment about the CB axis:

\[
M_{CB} = \overrightarrow{M} \cdot \mathbf{e}_{CB}
\]

\[
M_{CB} = -100\mathbf{i} + 200\mathbf{j} + 600\mathbf{k}
\]

\[
L_{CB} = \sqrt{(-7)^2 + (4)^2 + (-4)^2} = 9
\]

\[
\mathbf{e}_{CB} = -\frac{7}{9}\mathbf{i} - \frac{4}{9}\mathbf{j} - \frac{4}{9}\mathbf{k} = -0.778\mathbf{i} - 0.444\mathbf{j} - 0.444\mathbf{k}
\]

\[
M_{CB} = \left[ -100\mathbf{i} + 200\mathbf{j} + 600\mathbf{k} \right] \cdot \left[ -\frac{7}{9}\mathbf{i} - \frac{4}{9}\mathbf{j} - \frac{4}{9}\mathbf{k} \right]
\]

\[
= 100(\frac{7}{9}) - 200(\frac{4}{9}) - 600(\frac{4}{9})
\]

\[
= -277.8
\]