EXAM 5
Exam Date: November 21st, 2016, 8am
Room 206
50 Minute Time Limit

EXAM FORMAT
Students are allowed one 8 ½” x 11” handwritten sheet of his or her own notes, the AISC steel manual, and Chopra’s text.

Bonus Questions (0.1 points each)
List the winning teams of the National Students Steel Bridge Competition for each year:

2. 2008: University of California, Berkeley
3. 2009: SUNY Canton
4. 2010: North Dakota State University
5. 2011: Lakehead University
6. 2012: University of California, Berkeley
7. 2013: University of California, Berkeley
8. 2014: University of California, Davis
9. 2015: University of Florida
10. 2016: École de Technologie Supérieure

List Lafayette’s place at the National Students Steel Bridge Competition for each year:

1. 2007: 5th
2. 2008: DNQ
3. 2009: 7th
4. 2010: 7th
5. 2011: disqualified (lateral slide)
6. 2012: DNQ (failed lateral at regionals by 0.01”)
7. 2013: disqualified (lateral slide)
8. 2014: 6th
9. 2015: 5th
10. 2016: 4th
1. (100 points). Determine the natural periods and mode shapes for the two-story simple-braced building if it is considered to be a 2-DOF structure, with degrees of freedom, $u_1$ and $u_2$. Draw the mode shapes, indicating the eigenvector for each mode.

- All braces are considered to be tension-only (i.e., they buckle if subjected to compression), with area of 1 in$^2$.
- Assume that the axial deformation of the beams and columns can be neglected (i.e., the columns and beams are large, compared with the braces).
- All connections are simple pins. All material is steel.
- Assume 5% damping.

\[
\begin{align*}
K_1 &= \frac{(1in^2)(29000 ksi)}{480^2} = 36.57 kips/ft \\
K_2 &= 36.57 kips/ft \\
K &= \begin{bmatrix}
72.33 & -38.67 \\
-38.67 & 28.67
\end{bmatrix}
\end{align*}
\]

\[
K - \omega^2 M = 0
\]

\[
\begin{align*}
\det [K - \omega^2 M] &= 0 \\
(72.33 - \omega^2)(28.67 - 0.5\omega^2) - (-38.67)(-38.67) &= 0 \\
\omega_1^2 &= 22.6504 \Rightarrow \omega_1 = 4.759\text{ rad/s} \\
\omega_2^2 &= 132.016 \Rightarrow \omega_2 = 11.490\text{ rad/s}
\end{align*}
\]

Mode 1:
\[
\begin{bmatrix}
54.6529 & -38.67 \\
-38.67 & 27.3416
\end{bmatrix}\begin{bmatrix}
\phi_1 \\
\phi_2
\end{bmatrix} = \begin{bmatrix}
0 \\
0
\end{bmatrix} \Rightarrow \begin{cases}
\phi_1 = 1.000 \\
\phi_2 = 1.414
\end{cases}
\]

Mode 2:
\[
\begin{bmatrix}
-54.6529 & -38.67 \\
-38.67 & 27.3416
\end{bmatrix}\begin{bmatrix}
\phi_1 \\
\phi_2
\end{bmatrix} = \begin{bmatrix}
0 \\
0
\end{bmatrix} \Rightarrow \begin{cases}
\phi_1 = 1.000 \\
\phi_2 = -1.414
\end{cases}
\]
\[ \omega_1^2 = 132.08 \]

\[ \varphi_{21} = -1.41 \]

\[ \varphi_{11} = 1 \]

\[ (7.734 - 22.65) \varphi_{12} = (34.67) \varphi_{22} \]

\[ \varphi_{12} = 1 \]

\[ \varphi_{22} = 1.414 \]

\[ \omega_2^2 = 22.65 \]

\[ \varphi_{22} = 1.414 \]

\[ \varphi_{12} = 1 \]

\[ \varphi_{22} = 1.41 \]