Case Study 3

Scenario: A 1991 Jeep Cherokee (Jeep, Vehicle A) with a female driver and passenger were northbound and attempting to make a left turn into the parking lot of a department store in the process crossing two southbound lanes. Traffic was backed up in the left lane; however, a motorist in the south bound inside (left) lane had stopped with sufficient space for her to turn and waived the Jeep through. Concurrently, a 1997 Nissan Pathfinder (Nissan, Vehicle B), with a female driver, was southbound in the right southbound lane, when the front of the Nissan impacted the right rear of the Jeep. There was an estimated 10 feet of pre-impact skid marks from the Nissan noted in the police report but no other measurements. The police report sketch showed the final rest angle of the Jeep at approximately 20 degrees from north and the angle of the Nissan at approximately 183 degrees from north. The speed limit for the roadway on which the Nissan was traveling was 35 miles per hour. A scale drawing is shown in Figure 5-19.
The position of the vehicles at impact was estimated based on the geometry of the intersection, the traffic crash report and the statements of the two drivers.

The damage to the Jeep is shown on Figure 5-20, and the damage to the Nissan is shown on Figures 5-21 and 5-22.
From the medical records, the driver of the Nissan weighed approximately 165 pounds. From the depositions, the driver and passenger of the Jeep each weighed approximately 180 pounds.

Data for the vehicles are as follows:

<table>
<thead>
<tr>
<th></th>
<th><strong>Jeep (Vehicle A)</strong></th>
<th><strong>Nissan (Vehicle B)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Length (L_V)</td>
<td>13.75 ft</td>
<td>14.83 ft</td>
</tr>
<tr>
<td>Overall Width (W_V)</td>
<td>5.92 ft</td>
<td>6.00 ft</td>
</tr>
<tr>
<td>Wheel Base (L_{wb})</td>
<td>8.42 ft</td>
<td>8.83 ft</td>
</tr>
<tr>
<td>A (CG to front axle)</td>
<td>3.62 ft</td>
<td>3.89 ft</td>
</tr>
<tr>
<td>B (CG to rear axle)</td>
<td>4.80 ft</td>
<td>4.95 ft</td>
</tr>
<tr>
<td>X_F (CG to front bumper)</td>
<td>5.87 ft</td>
<td>6.30 ft</td>
</tr>
<tr>
<td>X_R (CG to front bumper)</td>
<td>7.88 ft</td>
<td>8.53 ft</td>
</tr>
<tr>
<td>Curb weight</td>
<td>2980 lbs_f</td>
<td>4143 lbs_f</td>
</tr>
<tr>
<td>Driver (female)</td>
<td>180 lbs_f</td>
<td>165 lbs_f</td>
</tr>
<tr>
<td>Passenger (female)</td>
<td>180 lbs_f</td>
<td></td>
</tr>
<tr>
<td>Total weight</td>
<td>3340 lbs_f</td>
<td>4308 lbs_f</td>
</tr>
</tbody>
</table>

The moments of inertia for the vehicles are calculated using Equation 1-35 as follows:

\[
I = \frac{m_{curb}}{K_G} \left( L_V^2 + W_V^2 \right) \left( 1 + K_M \left( \frac{m_{loaded} - m_{curb}}{m_{loaded}} \right) \right)
\]

Where, \( K_G = 12.2 \) and \( K_M = 0.656 \) for sport utility vehicles. The actual calculations are included on the spreadsheet, Figure 5-24.
The speed of the Jeep at the point of impact was initially estimated as 5 miles per hour for the purposes of estimating the rotational friction factor. The total rotation was approximately 100 degrees clockwise.

Based on the speed of the Jeep and the angle of rotation, $\xi$ can be read from Figure 4-1. For a speed of 0 mph, $\xi \approx 0.45$. The roadway friction was measured at 0.75. Therefore, $f_r$ is calculated as follows:

$$f_r = \xi f = (0.45)(0.75) \approx 0.34$$

The post impact angular velocity for the Jeep is calculated with the following formula:

$$\Psi_{A-2} = \sqrt{\frac{\Psi_{A-3/2} f_r a \mathcal{W}_A L_{wb-A}}{I_A}}$$

The actual calculations are performed in the spread sheet, Figure 5-23.

The speed of the Nissan at the point of impact was initially estimated as 20 miles per hour for the purposes of estimating the rotational friction factor. The total rotation was approximately 3 degrees clockwise.

Based on the speed of the Jeep and the angle of rotation, $\xi$ can be read from Figure 4-1. For a speed of 20 mph, $\xi \approx 0.04$. The roadway friction was measured at 0.75. Therefore, $f_r$ is calculated as follows:

$$f_r = \xi f = (0.04)(0.75) \approx 0.03$$

The post impact angular velocity for the Jeep is calculated with the following formula:

$$\Psi_{B-2} = \sqrt{\frac{\Psi_{B-3/2} f_r a \mathcal{W}_B L_{wb-B}}{I_B}}$$

The actual calculations are performed in the spread sheet, Figure 5-23.
The pre-impact angular velocity is generally negligible. In this case, the Nissan (Vehicle A) is traveling straight and is not rotating. Therefore $\Psi_{B-1} = 0$. 
The Jeep was turning at the point of impact, therefore, $\Psi_{A-2} \neq 0$, but is small enough to be neglected. For illustration purposes, the pre-impact angular velocity of the Jeep will be calculated. Assume the pre-impact speed of the Jeep is 5 miles per hour. From the scene diagram, the radius of the curve of the Buick’s path is approximately 35 feet.

From Equation 1-9:

$$V_A = r\Psi$$

Rearranging and applying the appropriate subscripts, the equation becomes:

$$\Psi_{A-1} = \frac{V_{A-1}}{r} = \frac{-5(1.466)}{30} = -0.24 \text{ rad/s}$$

Note the negative sign, which indicates that the pre-impact angular velocity is counterclockwise.

The spreadsheet allows the point of impact to be translated into vehicle coordinates, which is axial and lateral with the origin at the center of gravity. Forward and to the right are positive. The vehicle referenced coordinates are determined as follows:

For the Jeep, the impact was centered just behind the rear wheel on the right side. The x direction coordinate is approximately –5.00 feet (Note the negative sign signifies that the impact is behind the center of gravity and the magnitude is slightly larger than $B$, the distance from the center of gravity and the rear axle). The y coordinate is lateral and is to the right and approximately half of the vehicle width. The assigned coordinate is 2.8 feet.

For the Nissan, the impact is centerline front, therefore the x coordinate assigned is 6.1. Note it is positive with a magnitude slightly less than $X_F$. The y coordinate is 0, signifying that it is centerline.

From the spreadsheet, Figure 5-23, the speed of the Jeep at impact was 5.7 mph and the speed of the Nissan was 23.6 mph.

The pre braking speed of the Nissan is calculated as follows:
\[ S = \sqrt{(23.6)^2 + 30(0.75)(10)} = 28.0 \text{ mph} \]