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.

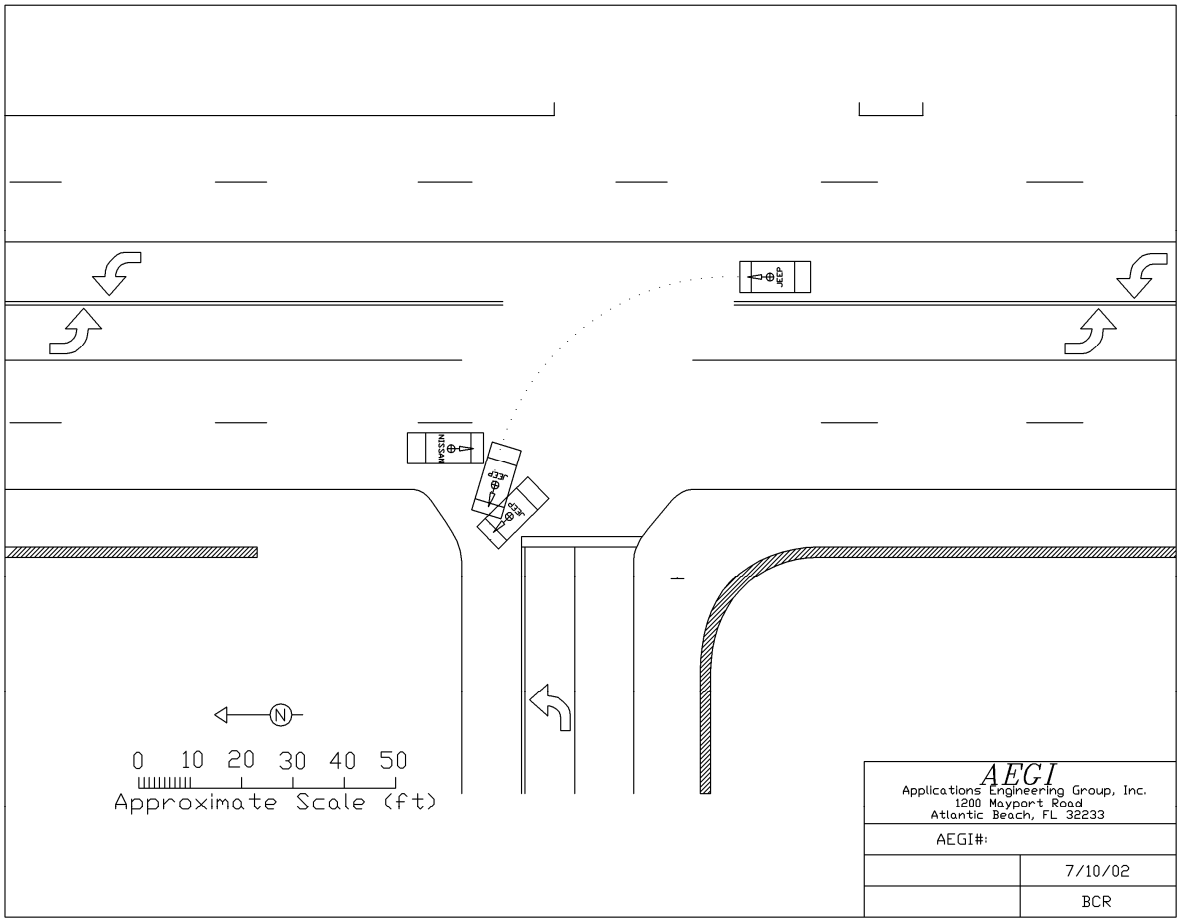

Figure 5-19

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.

Figure 5-20

Figure 5-21

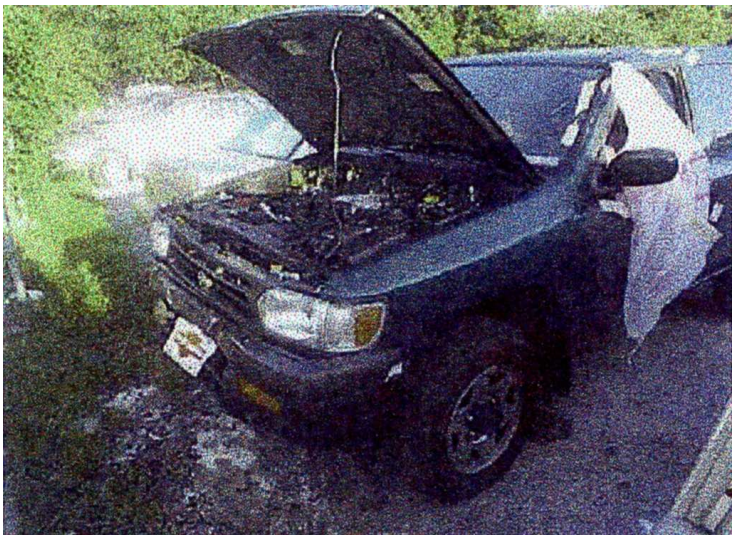

Figure 5-22

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:

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

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

$$\dot{\Psi}_{A-2} = \sqrt{\frac{\Psi_{A-3/2} f_{r-A} W_A L_{wb-A}}{I_A}}$$

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, ξ 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:

$$\dot{\Psi}_{A-2} = \sqrt{\frac{\Psi_{B-3/2} f_{r-B} W_B L_{wb-B}}{I_B}}$$

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, ξ 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:

$$\dot{\Psi}_{B-2} = \sqrt{\frac{\Psi_{B-3/2} f_{r-B} W_B L_{wb-B}}{I_B}}$$

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

Genral Roational Momentem Calculations

AEGI file:
Case name: Case Study 3

Data		
Parameter	Vehicle A	Vehicle B
Make/Model	`1991 Jeep Cherokee	1997 Nissan Pathfinder
car, van, utility, or pickup	utility	utility
Length (L_v)	13.75 ft	14.83 ft
Width (W_v)	5.92 ft	6 ft
Wheel base (L_{wb})	8.42 ft	8.83
A (front axle to CG)	3.62	3.89
B (rear axle to CG)	4.8	4.95
XF (front bumper to CG)	5.87	6.3
XR (rear bumper to CG)	7.88	8.53
Curb Weight (W_{curb})	2980 lb_f	4143 lb_f
Loaded Weight (W_{loaded})	3340 lb_f	4308 lb_f
Pre-impact angle (Ψ_1)	280 deg.	180 deg.
Final rest angle (Ψ_3)	20 deg.	183 deg.
# of complete rotations to final rest	0	0
Pre-impact ang. vel. (Ψ_1-dot)	-0.24 rad/s	0 rad/s
Ψ_1-dot rotational dir. (cw or ccw)	ccw	cw
Post-impact rotational dir. (cw or ccw)	cw	cw
x-dir (veh ref) impact from CG (fwd +)	-5 ft	6.1 ft
y-dir (veh ref) impact from CG (right +)	2.8 ft	0 ft
rotational friction factor (ξ)	0.45	0.04
Roadway friction	0.75	0.75

Intermediate calcs	
a=	0.0325242
b=	0.0331959
c=	0.0056153
$L_{A\text{-}bx}$=	0.0328714
$L_{A\text{-}cx}$=	0.0055604
$L_{A\text{-}ay}$=	0.0922307
$L_{A\text{-}cy}$=	0.0159235
$L_{B\text{-}bx}$=	-0.069823
$L_{B\text{-}cx}$=	-0.011811
$L_{B\text{-}ay}$=	8.381E-18
$L_{B\text{-}cy}$=	1.447E-18
K=	0.0866703
M=	0.0317406
N=	-0.011811
P=	0.0667115

Calculated Data		
Parameter	Vehicle A	Vehicle B
Curb mass (m_{curb})	92.5 slugs	128.7 slugs
Loaded mass (m_{loaded})	103.7 slugs	133.8 slugs
K_G	12.2	12.2
K_M	0.656	0.656
Yaw Moment of Intertia (I)	1820.2 lb_f-ft-s^2	2766.9 lb_f-ft-s^2
$\Psi_{3\text{-}1}$	100 deg	3 deg
rotational friction (f_r)	0.3375	0.03
Pre-impact ang. vel. (Ψ_1-dot)	-0.24 rad/s	0 rad/s
Post-impact ang. vel. (Ψ_2-dot)	3.016753 rad/s	0.146954 rad/s
$d_{I\text{-}x}$	1.889221 ft	-6.1 ft
$d_{I\text{-}y}$	5.410254 ft	7.47E-16 ft

Final Solution		
$V_{A\text{-}1}$=	8.32 ft/s	5.67 mph
$V_{B\text{-}1}$=	34.53 ft/s	23.55 mph

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 $\dot{\Psi}_{B-1} = 0$.

The Jeep was turning at the point of impact, therefore, $\dot{\Psi}_{A-2} \neq 0$, 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:

$$V_A = r\dot{\Psi}$$

Rearranging and applying the appropriate subscripts, the equation becomes:

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

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

The spread sheet 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:

$$S = \sqrt{(23.6)^2 + 30(0.75)(10)} = 28.0 \text{ mph}$$