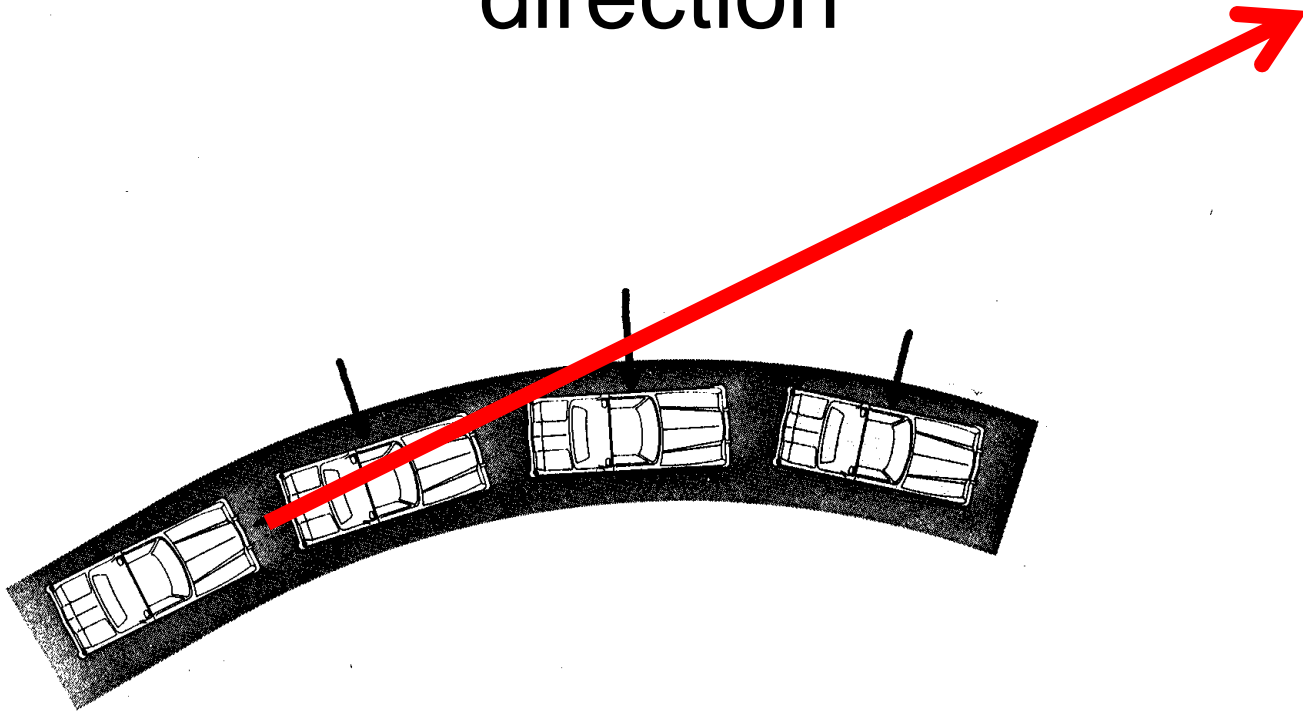




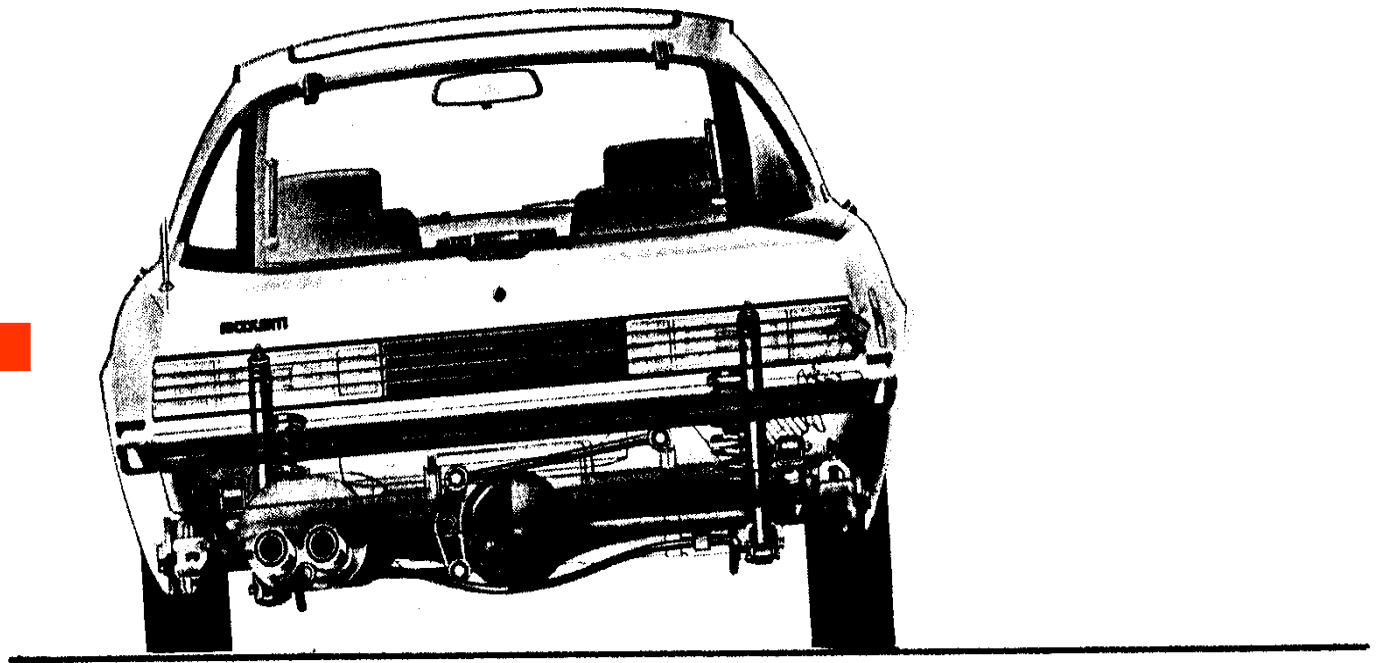
Single Vehicle – Loss of Control

the natural motion is to
continue in the same
direction



weight shifts to outside of turn

INERTIA

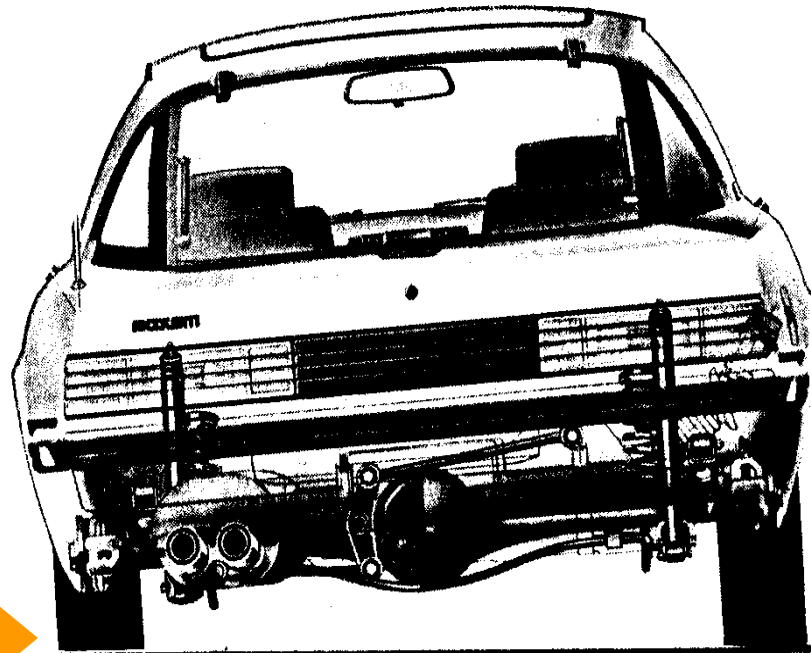


weight shifts to outside of turn

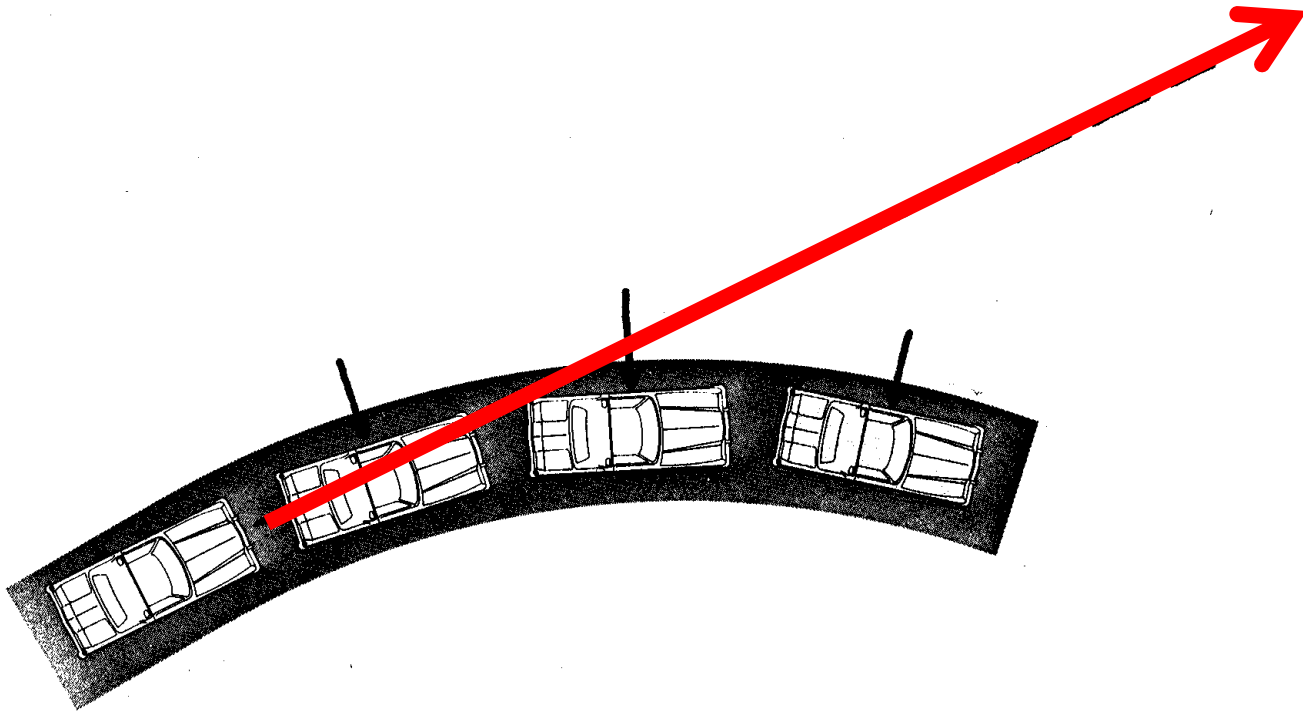
INERTIA



friction



a “yaw” occurs when the
tires lose traction



WHAT FACTORS AFFECT A LOSS OF TRACTION ?

speed

S

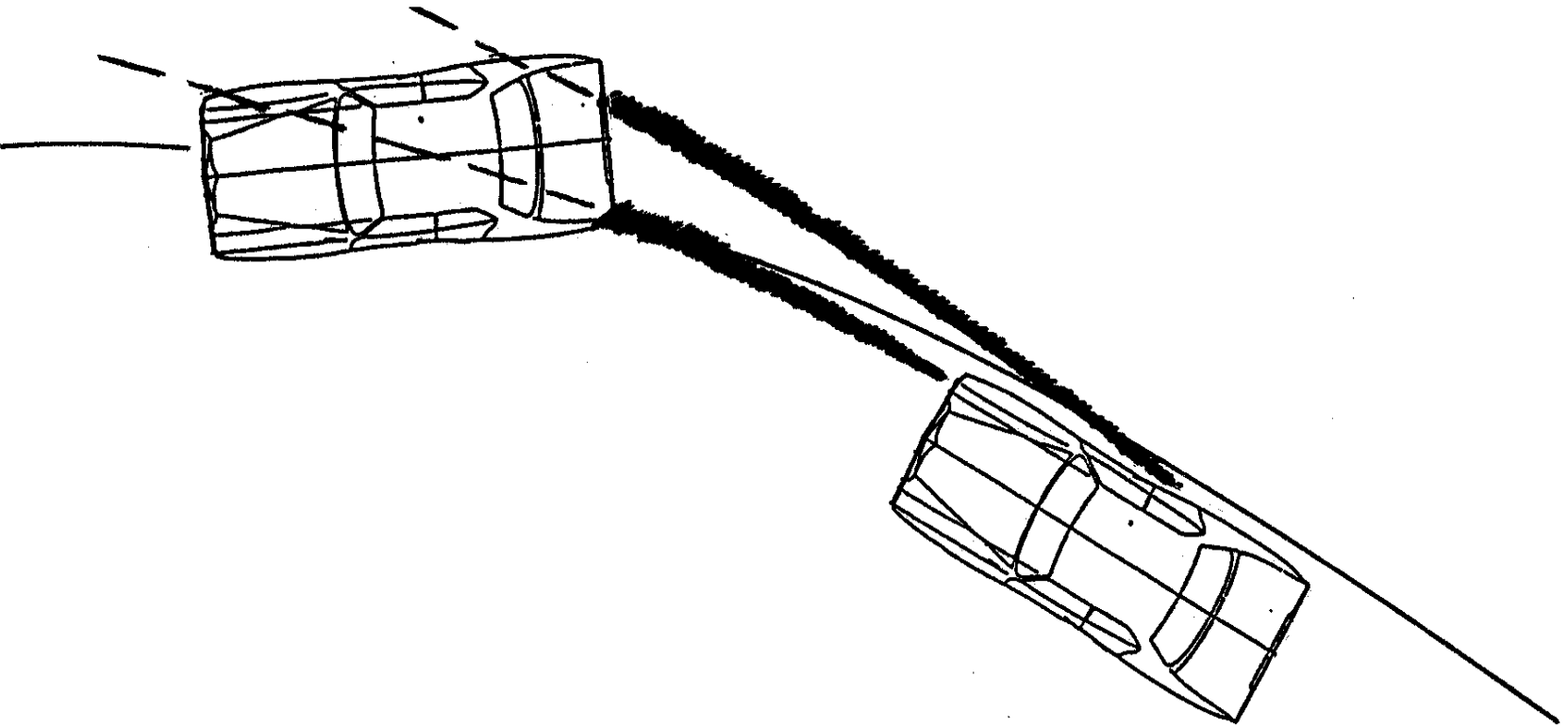
friction

f

path curvature

R

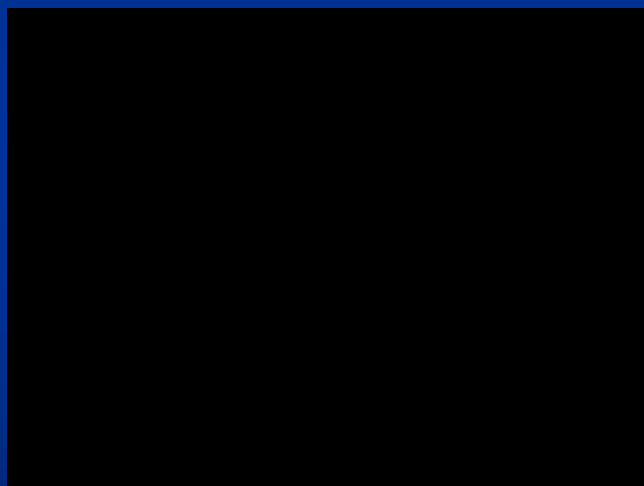
TRACKING OF OUTSIDE TIRES IN A YAW





In a
controlled
turn, front
tire tracks
outside
rear tire.

If the yaw is caused by the inertial motion of the vehicle, and not by other forces, it is called a **Critical Speed Yaw** or **CSY**.





Rear tire tracks outside front.

CSI

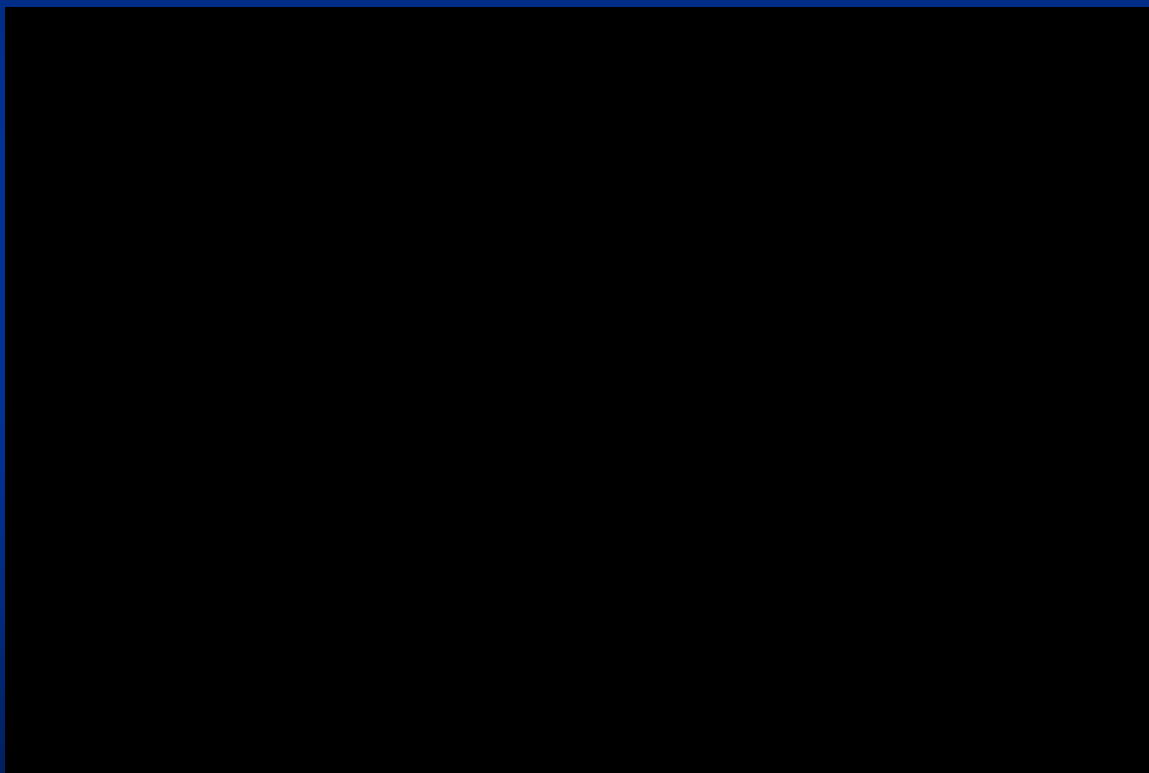


Front, outside tire mark is usually darkest.



The image shows a vast, flat asphalt surface, likely a parking lot or a large open area. In the background, there is a line of bare trees under a clear sky. A white arrow points from the word 'crossover' to a specific point on the asphalt where two curved tire tracks intersect.

crossover





Crossover is not visible



Crossover is not visible

“As a matter of clarity, they do NOT have to see the actual place where the outtracking begins (crossover), just that it has begun.”

Personal email conversation with
John Daily, March 29, 2013

A close-up photograph of a dark asphalt road surface. A white diagonal line runs from the bottom right towards the top right. To the left of this line, there is a series of closely spaced, parallel grooves or ridges in the pavement, which are the 'striations' mentioned in the text. The text '“striations”' is overlaid in white on the left side of the image.

“striations”



“striations”



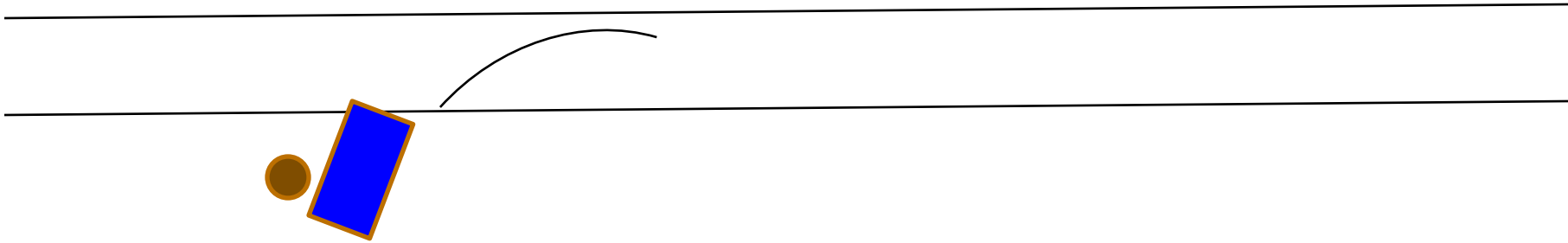
Goodyear

STANDARD 1000
F31234-000-442

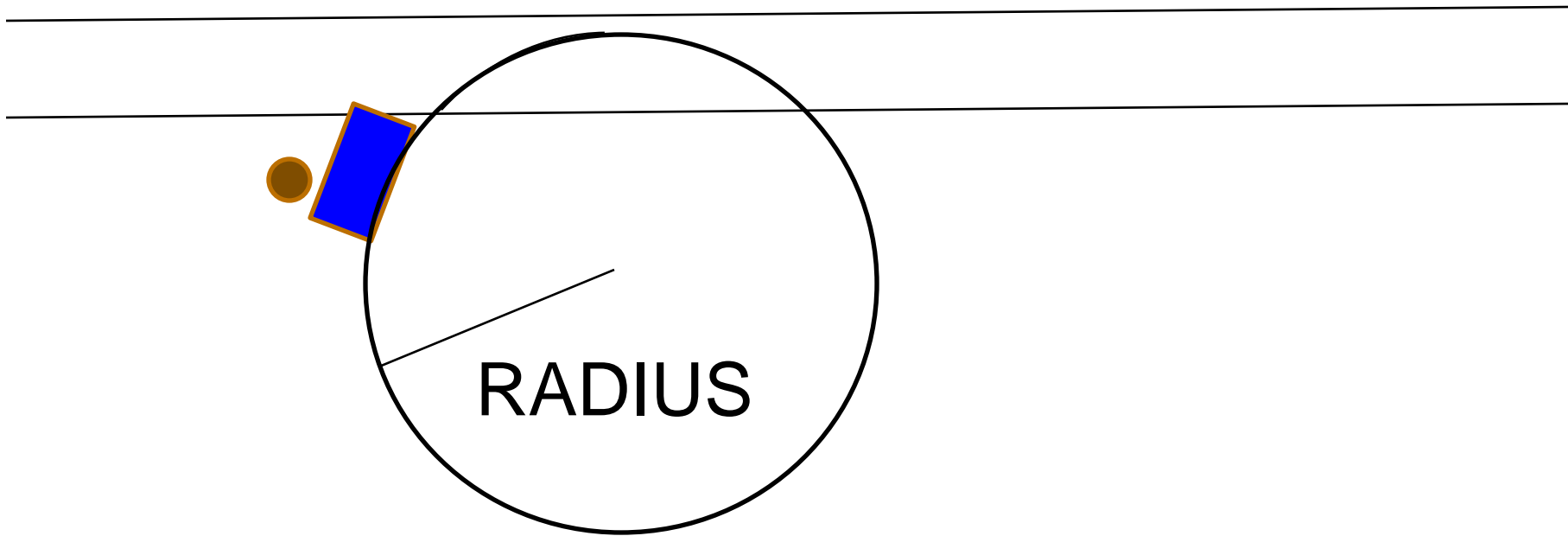
HOW DO WE DETERMINE

R





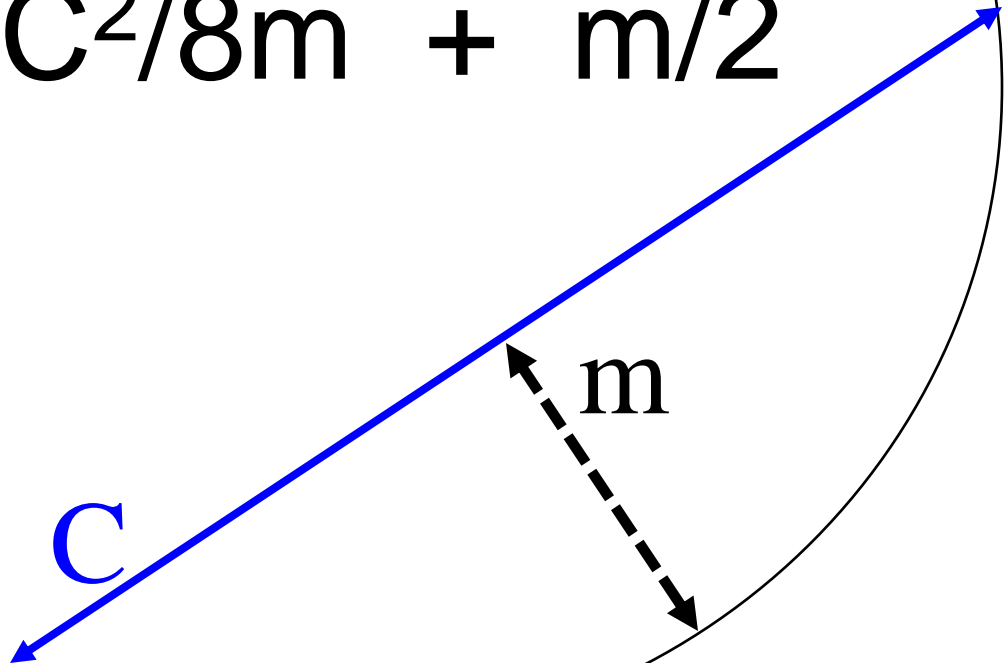
VEHICLE YAWS OFF ROAD,
STRIKES A TREE



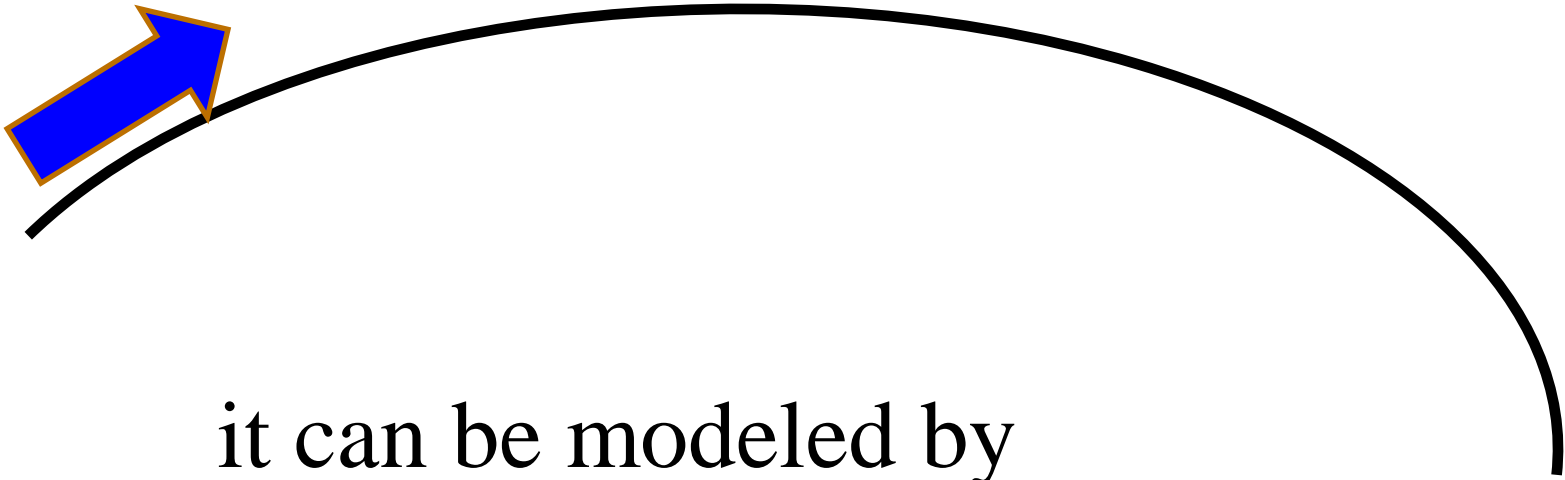
Geometry 101:

Finding the radius of a circle:

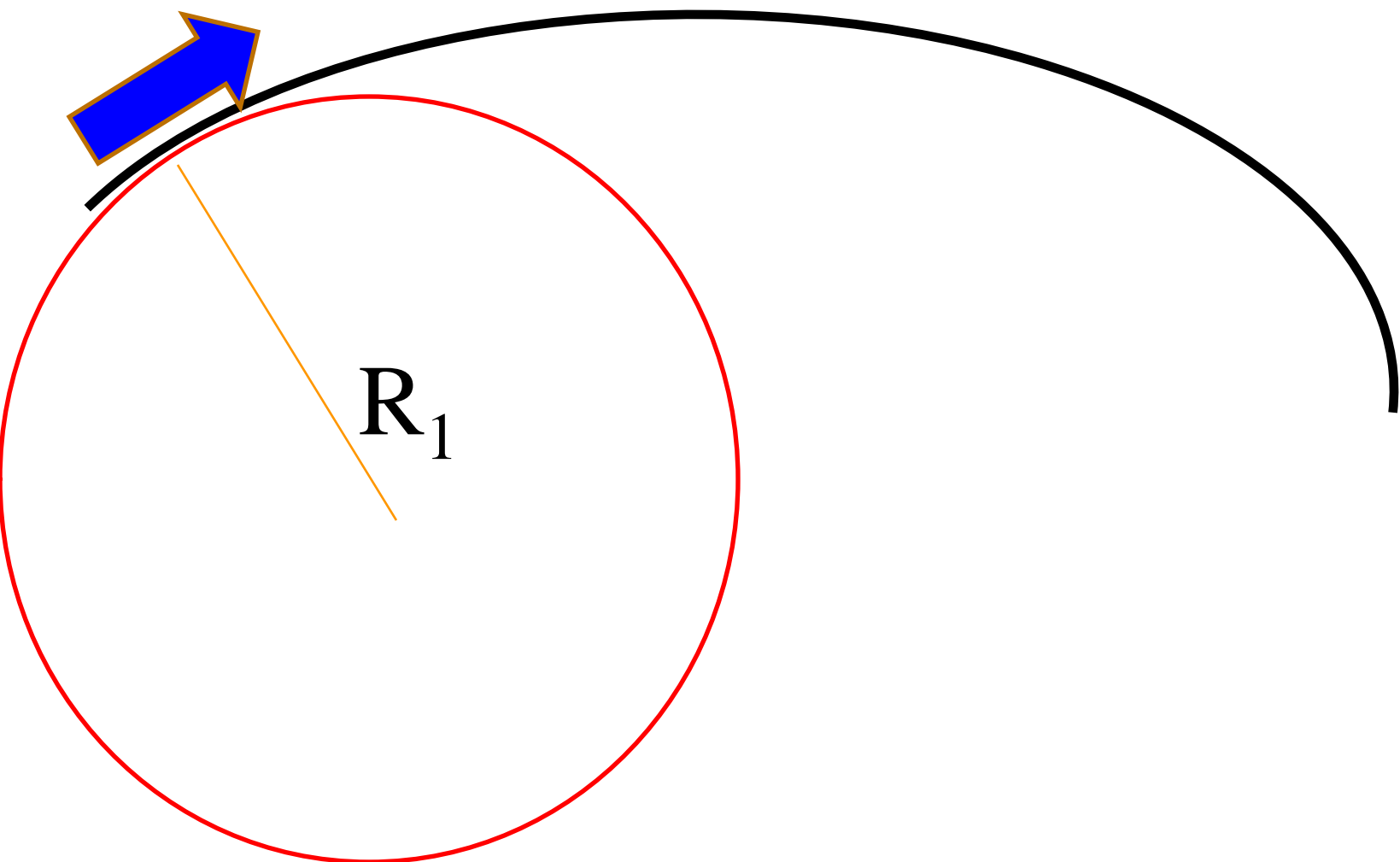
$$R = C^2/8m + m/2$$

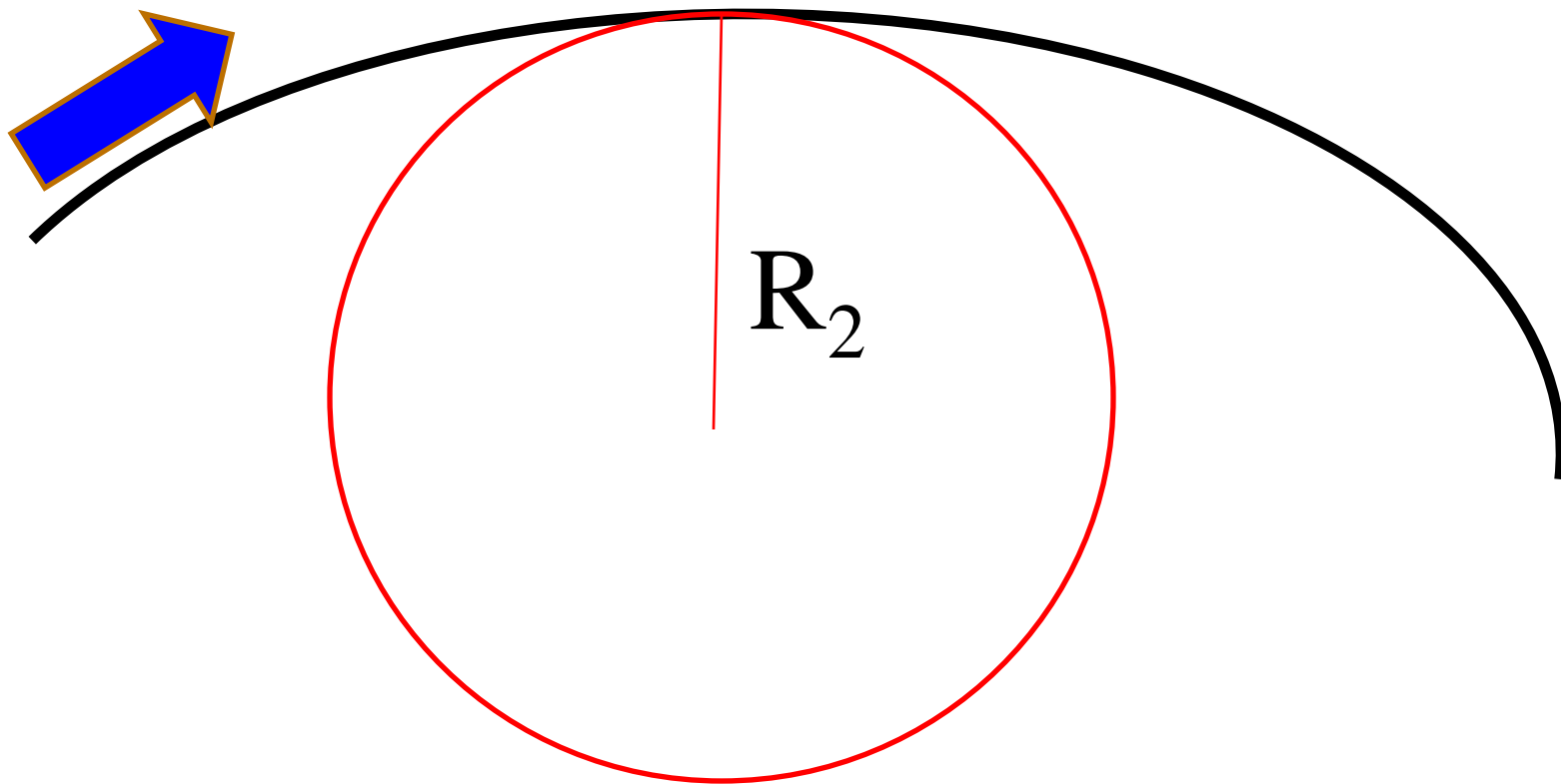


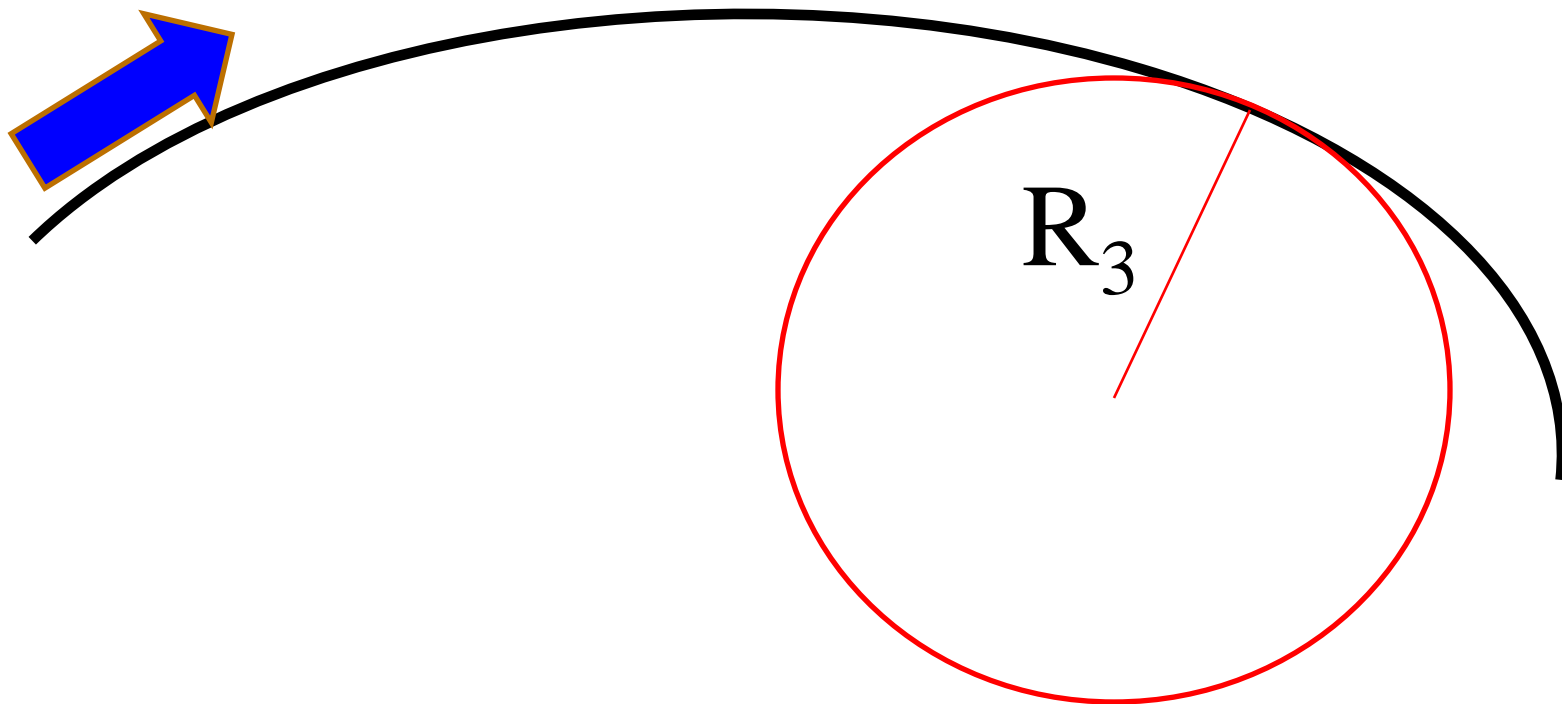
A yaw mark is not a true circle, but

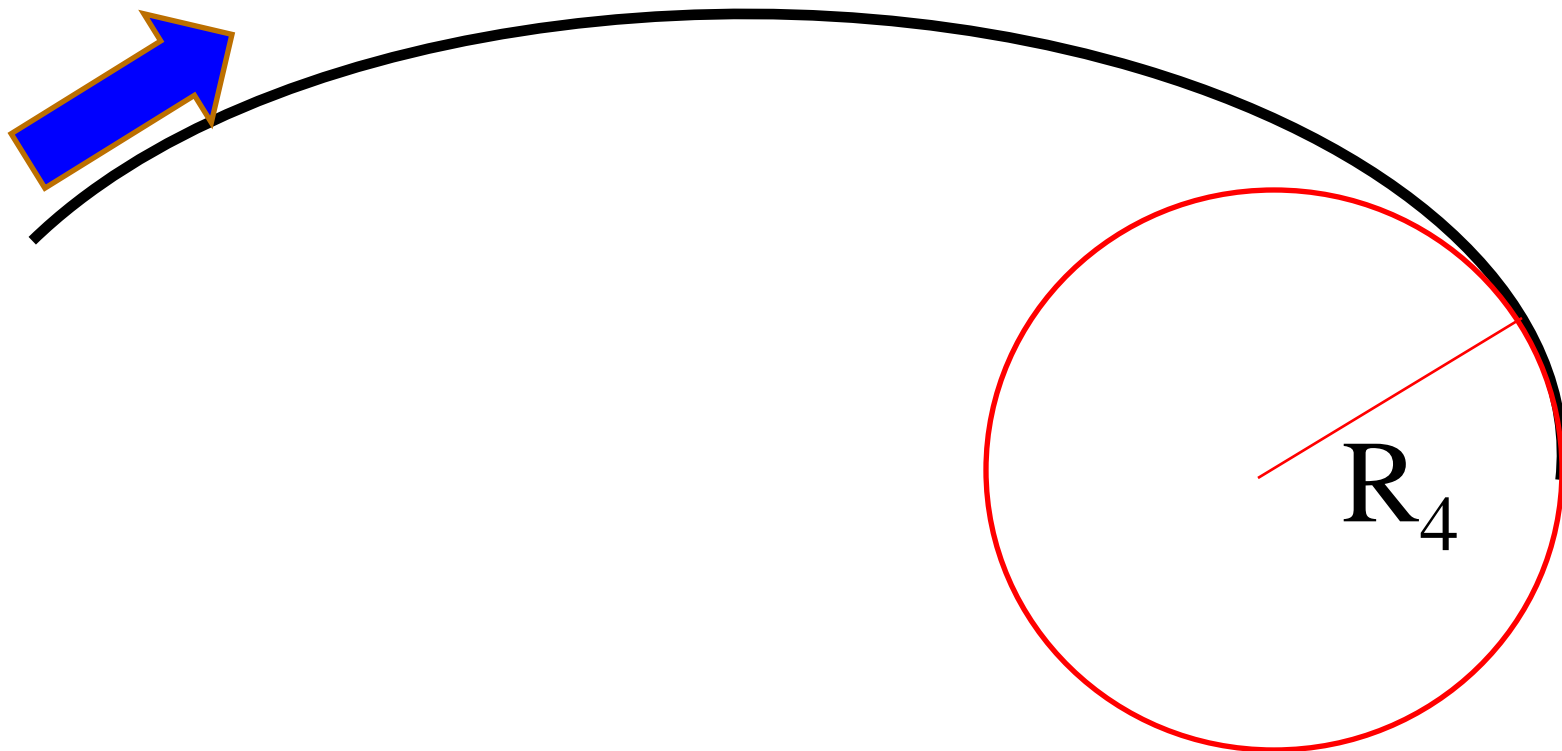


it can be modeled by
breaking it into circular segments.

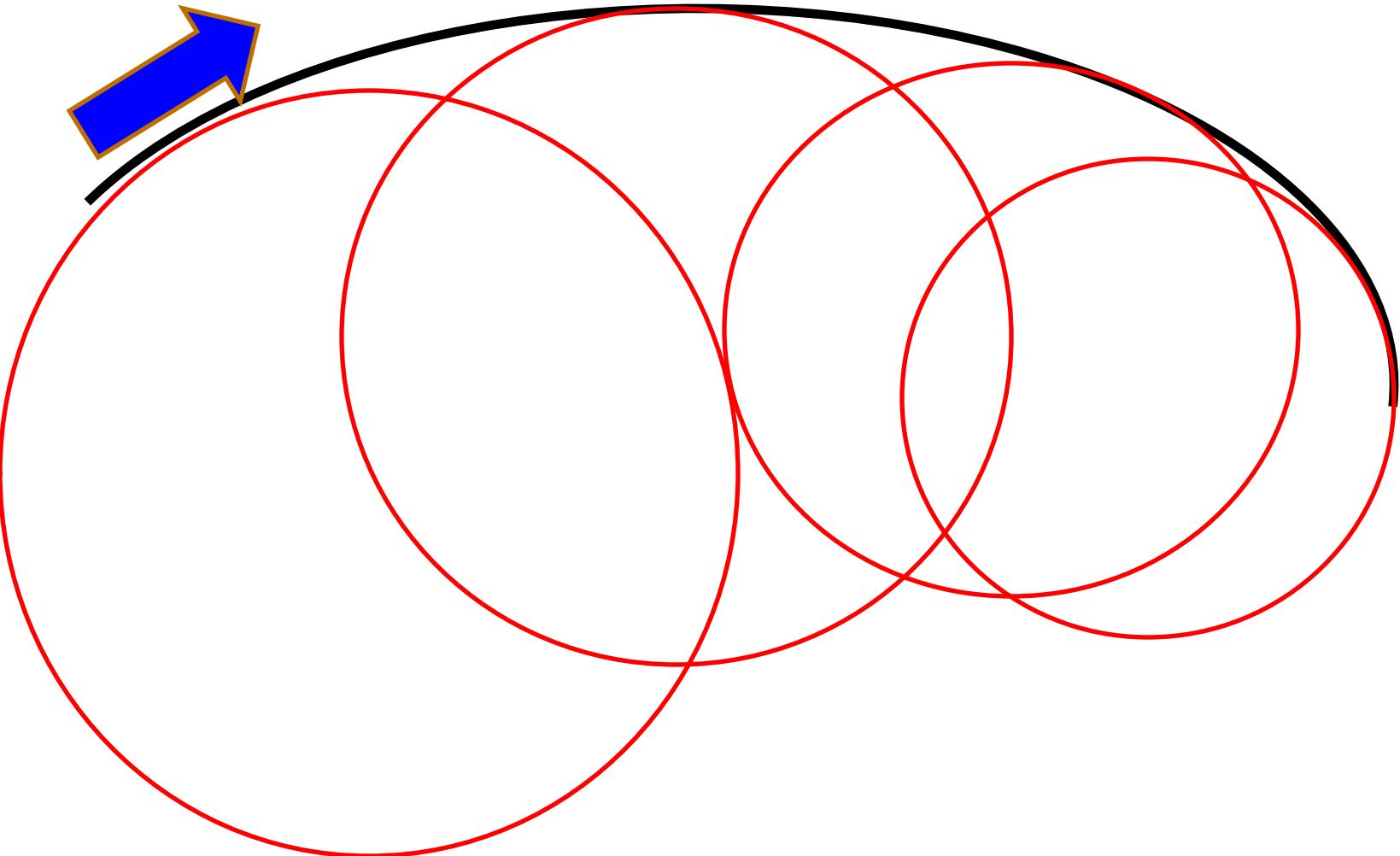








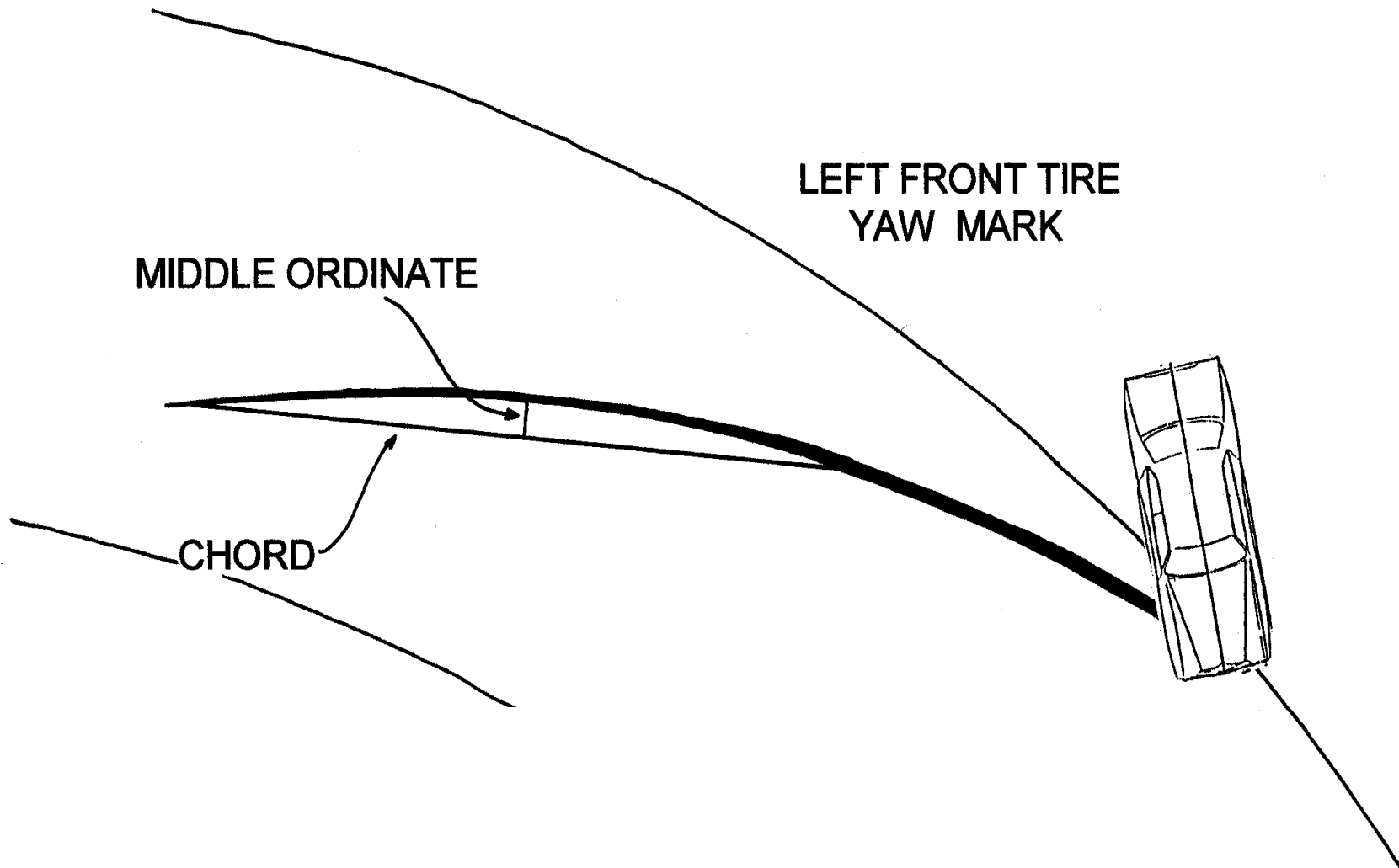
As the yaw continues,
the radius decreases

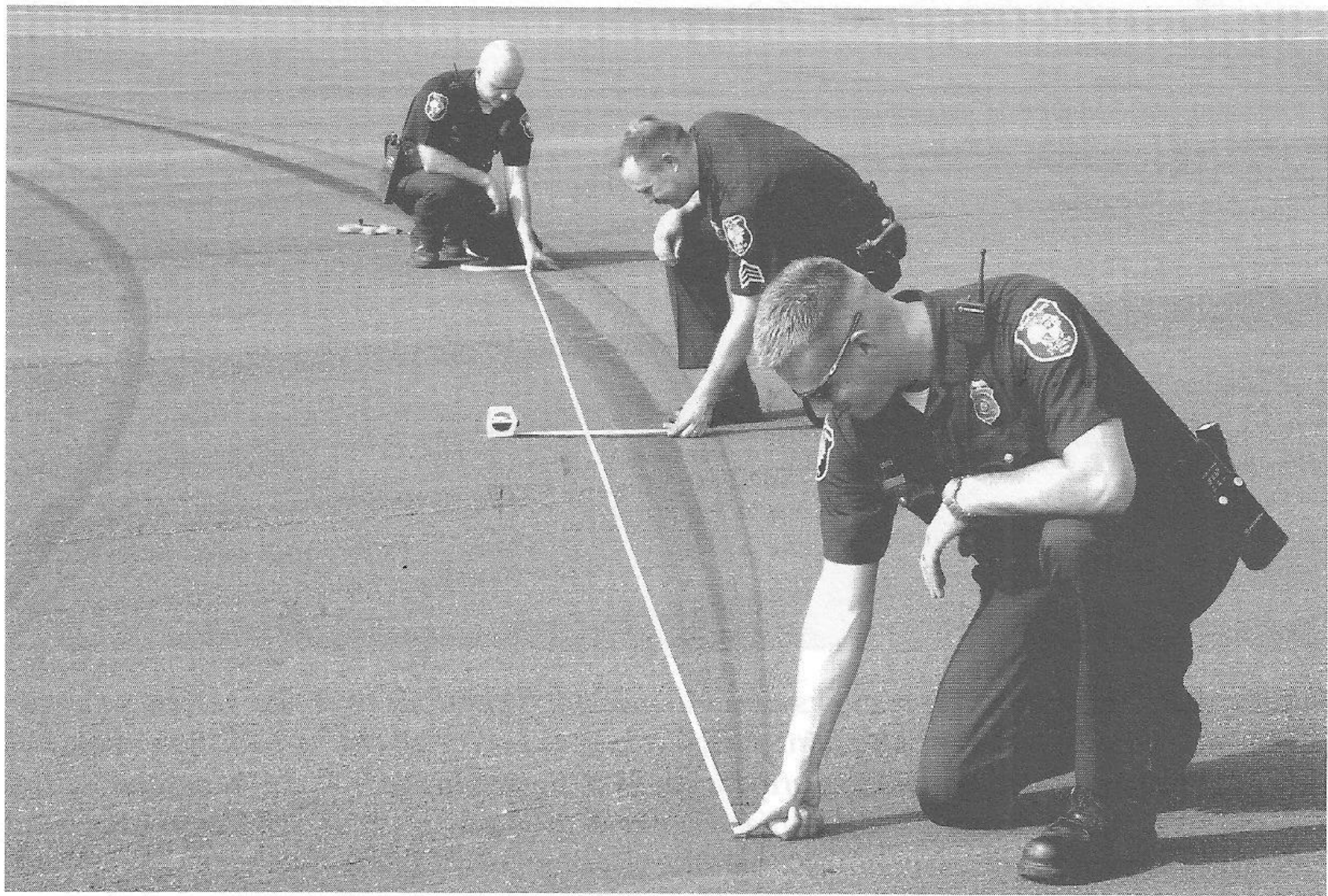


SAE # 2005-01-1189

“Validation of the Circular Trajectory Assumption in Critical Speed”

“The path carved out by a car as it creates a critical speed tire scuff was found to be well modeled by a simple circle.”





Where is the chord-middle
ordinate measurement made?

“First, we must identify the location where the outside rear tire tracks outside the corresponding front tire. This will be the location from which we measure the first chord.”

Fundamentals of Traffic Crash
Reconstruction, Daily, p. 439

Where is the chord-middle
ordinate measurement made?

As close as possible to the start
of the yaw.



the most sensitive
measurement – defense attack point



Investigation checklist:

Document the yaw
mark evidence

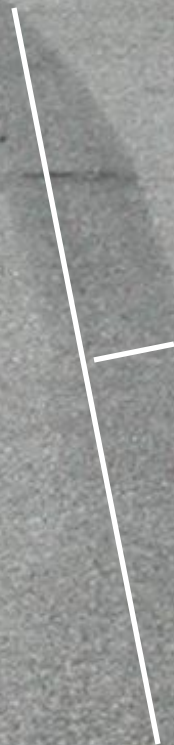
**STRIATIONS
RADIUS MEASUREMENT**

More about chord/mid ordinate
measurements:
either inside or outside

INSIDE



OUTSIDE



More about chord/mid ordinate
measurements:

either inside or outside

as close to start as possible



More about chord/mid ordinate
measurements:

either inside or outside

as close to start as possible

two measurements



“... a CSY mark should be long enough to measure two chords and middle ordinates. If the marks are too short to obtain two chords and middle ordinate measurements, then the maneuver is not a critical speed yaw.”

p. 441 Daily, Fundamentals of Traffic
Crash Reconstruction

More about chord/mid ordinate measurements:

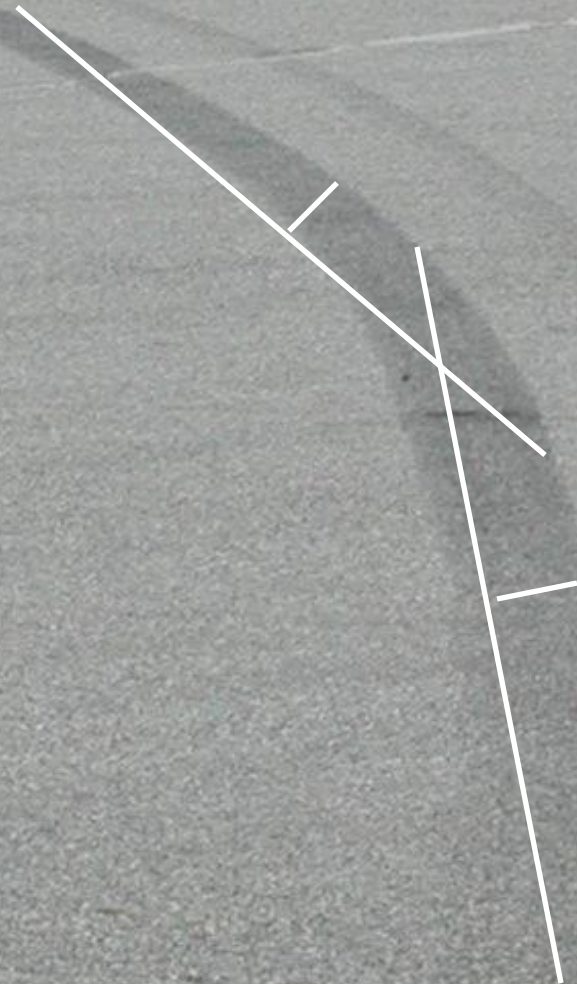
either inside or outside

as close to start as possible

two measurements

chords may overlap

OVERLAPPING MEASUREMENTS





CHORD LENGTH = 30 ft

MIDDLE ORDINATE = 6 in (.5 ft)

$$R = C^2 / 8m + m / 2$$

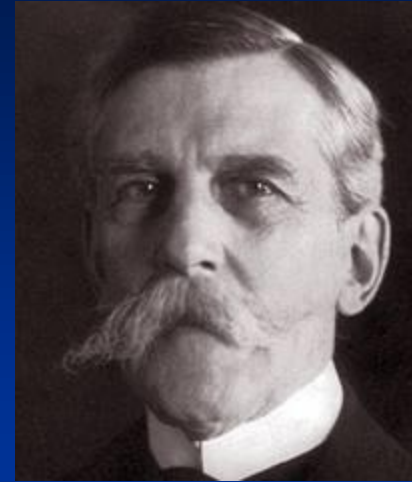
Calculate the radius :

$$C = 30 \text{ ft} \quad M = .5 \text{ ft}$$

$$R = 30(30) / 8(.5) + .5 / 2 = 225 \text{ ft}$$

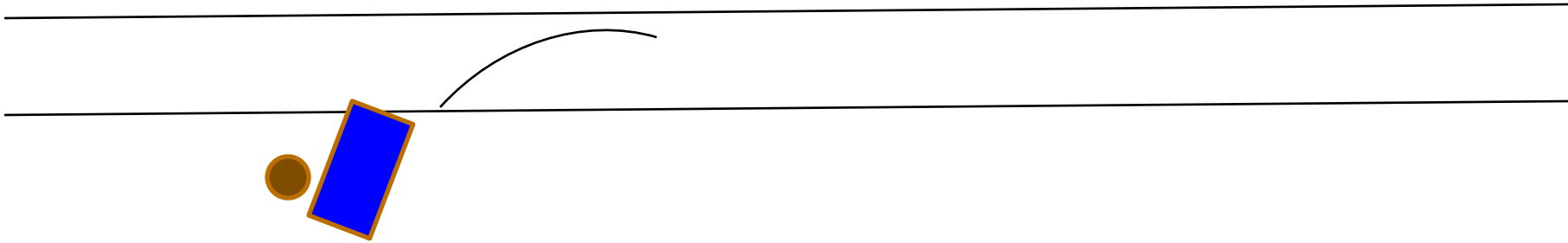
DEFENSE:

***DEFENSE EXPERT
QUESTIONS CSY
MEASUREMENTS***

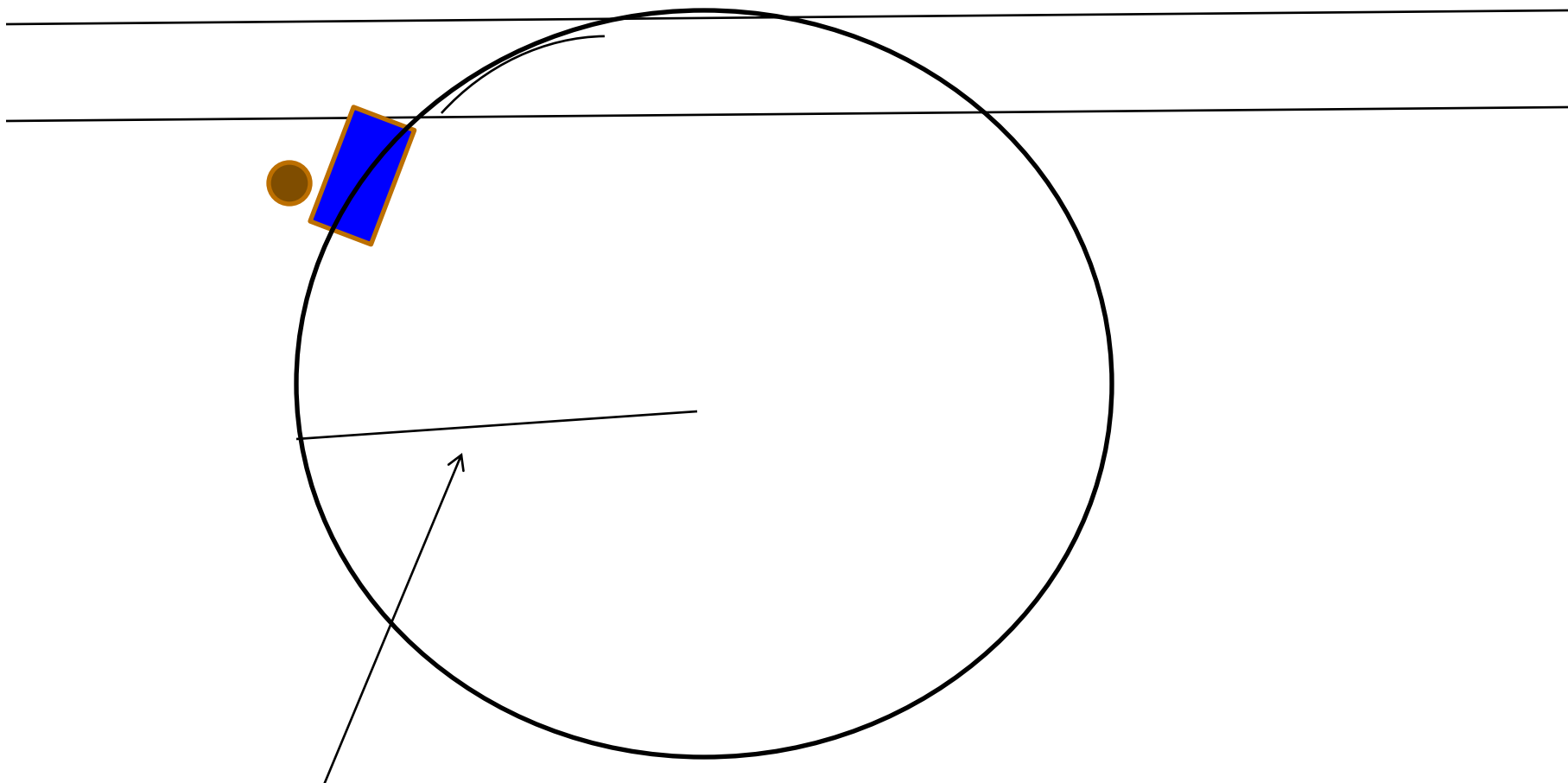


“Do not be bullied out of your
common sense by the expert.”

Oliver Wendell Holmes, Jr.



VEHICLE YAWS OFF ROAD,
STRIKES A TREE



RADIUS

DEFENSE EXPERT'S REPORT:

“The evidence used by police to determine speed included only 30 ft of the tire mark, which was assumed to be part of a circle having a total circumference of 2100 ft;

As such less than 2% of the evidence was used by police.

As such less than 2% of the
evidence was used by police.

BULLSCHEIN

“An error of as little as 4 inches in the middle ordinate would produce a significant error in the speed estimate.”

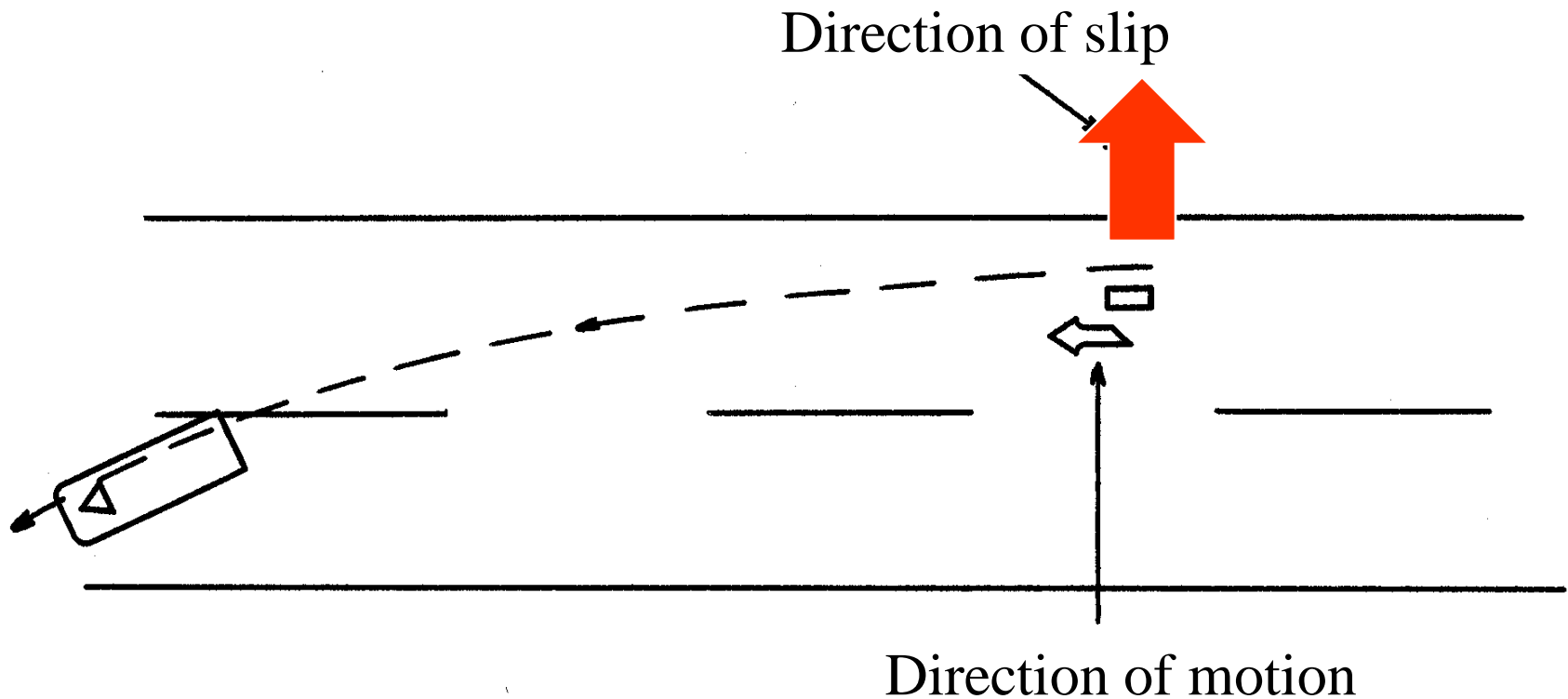
“An error of as little as 4 inches
in the middle ordinate would
produce a difference in
the area

BULLSCHEIN

HOW DO WE DETERMINE



Drag factor must be determined
in the direction of slip.



direction of slip



Critical Speed Yaw (CS Y) equation :

$$S = \sqrt{15 R f}$$

Yaw Speed nomograph:

Critical Speed Yaw (CSY):

drag factor	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
yaw radius (ft)	24.4	25.9	27.3	28.7	30.0	31.2	32.4	33.5	34.6	35.7	36.7
100	30.0	31.8	33.5	35.1	36.7	38.2	39.6	41.0	42.4	43.7	45.0
150	34.6	36.7	38.7	40.6	42.4	44.1	45.8	47.4	48.9	50.4	51.9
200	38.7	41.0	43.3	45.4	47.4	49.3	51.2	53.0	54.7	56.4	58.0
250	42.4	45.0	47.4	49.7	51.9	54.0	56.1	58.0	60.0	61.8	63.6
300	45.8	48.6	51.2	53.7	56.1	58.4	60.6	62.7	64.8	66.8	68.7
350	48.9	51.9	54.7	57.4	60.0	62.4	64.8	67.0	69.2	71.4	73.4
400	51.9	55.1	58.0	60.9	63.6	66.2	68.7	71.1	73.4	75.7	77.9
450	54.7	58.0	61.2	64.2	67.0	69.8	72.4	75.0	77.4	79.8	82.1
500	57.4	60.9	64.2	67.3	70.3	73.2	75.9	78.6	81.2	83.7	86.1
550	60.0	63.6	67.0	70.3	73.4	76.4	79.3	82.1	84.8	87.4	90.0
600	62.4	66.2	69.8	73.2	76.4	79.6	82.6	85.5	88.3	91.0	93.6
650	64.8	68.7	72.4	75.9	79.3	82.6	85.7	88.7	91.6	94.4	97.2
700	67.0	71.1	75.0	78.6	82.1	85.5	88.7	91.8	94.8	97.7	100.6
750	69.2	73.4	77.4	81.2	84.8	88.3	91.6	94.8	97.9	100.9	103.9
800	71.4	75.7	79.8	83.7	87.4	91.0	94.4	97.7	100.9	104.1	107.1
850	73.4	77.9	82.1	86.1	90.0	93.6	97.2	100.6	103.9	107.1	110.2
900	75.4	80.0	84.4	88.5	92.4	96.2	99.8	103.3	106.7	110.0	113.2
950	77.4	82.1	86.6	90.8	94.8	98.7	102.4	106.0	109.5	112.9	116.1
1000											

Example:

700 ft yaw radius, with drag factor = 0.80, speed = 91.6 mph

Filename: CSY CHART

yaw radius = 225 ft

drag factor = .82

What is the speed estimate from
the yaw mark ?



yaw radius = 225 ft

drag factor = .82

What is the speed estimate from
the yaw mark ?

$$S = \sqrt{15 f R} = \sqrt{15(.82)(225)}$$

yaw radius = 225 ft

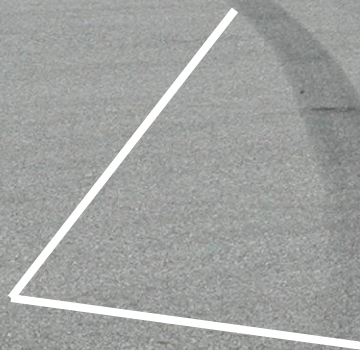
drag factor = .82

What is the speed estimate from
the yaw mark ?

$$S = \sqrt{15 f R} = \sqrt{15(.82)(225)}$$

52.6 mph

$S = 52.6 \text{ mph}$



DEFENSE:

***CSY FORMULA IS
INVALID***

***(BASED ON PUBLISHED
TESTING)***

SAE #950137 Dickerson, et.al.

“The critical speed formula calculations were greater than the measured velocities of the test vehicle in all test results.”

ATTACK: CSY FORMULA
IS INVALID.

SAE #950137 Dickerson, et.al.

Testing included *double-step
steer maneuvers* that produced
high slip angles. (NOT CSY
MANEUVERS)

ATTACK: CSY FORMULA
IS INVALID.

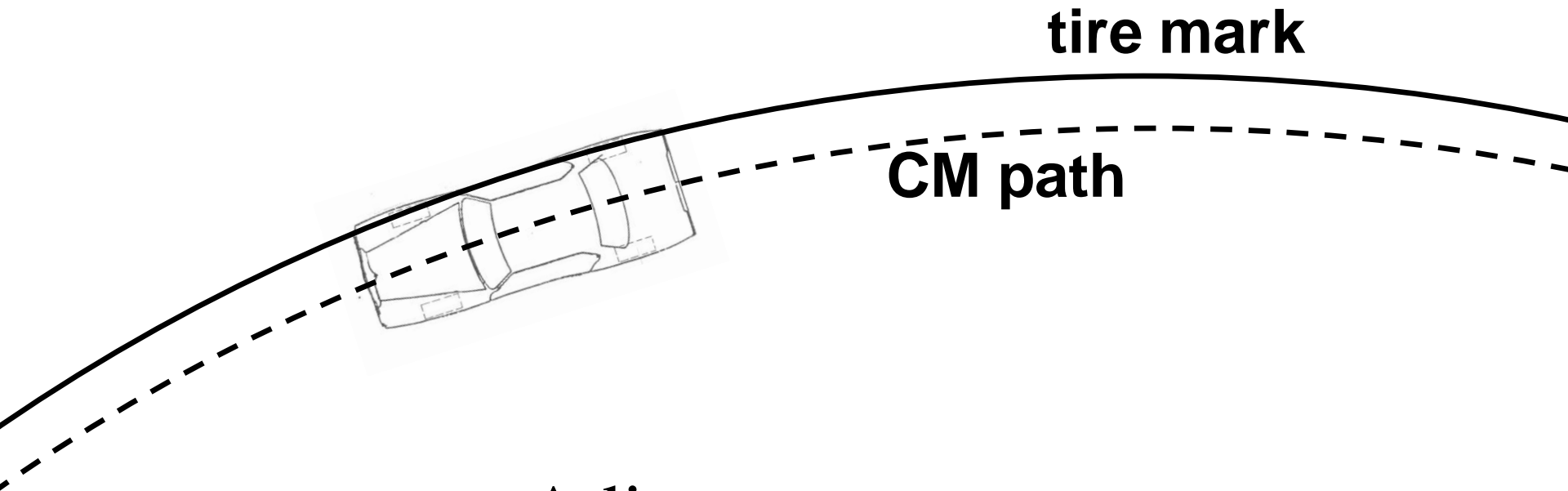


BULLSCHTEIN

CSY Test Results

Date	Location	Corrected Radius R_1 / R_2	Drag factor from Skid Test	<u>Longitudinal</u> <u>f</u> Calculated / Measured	Calculated Speed, MPH	Radar or Integrated Speed
July 2002	Wisconsin	84.29 / 71.29	0.83	0.18/0.18	32.28	33
Nov. 2003	Minnesota	123.2/108.9	0.77	0.18/0.181	37.59	38
Nov. 2003	Minnesota	105.4/92.6	0.77	0.16/0.19	34.77	36
July 2003	Ohio	73.74/53.01	0.79	0.27/0.26	28.91	29.5
Oct. 2003	Wyoming	213.6/193.6	0.64	0.21/0.21	45.13	46
Oct. 2003	Wyoming	112.4/94.5	0.64	0.18/0.20	32.73	33
April 2004	New Mexico	110.5/100.3	0.77	0.13/0.13	35.61	36
Oct. 2004	Wisconsin	125.3/116.3	0.89	0.13/NA	40.75	41
May 2005	Illinois	82.46/71.16	0.78	0.15/0.26	30.96	33

Defense asserts that the radius is not the radius of the motion of the center of mass of the vehicle.



Adjustment:

$$R_{\text{CM}} = R_{\text{tire mark}} - TW/2$$

yaw radius = $225 - 2.5 = 222.5$ ft

drag factor = .82

What is the speed estimate using the adjusted radius ?

$$S = \sqrt{15 f R} = \sqrt{15(.82)(222.5)}$$

52.3 mph

A curved tire mark, but
not a CSY.



1997 Toyota 4Runner SR5 4x2 Automated Rollover Crash Test

Bellion SAE 970955

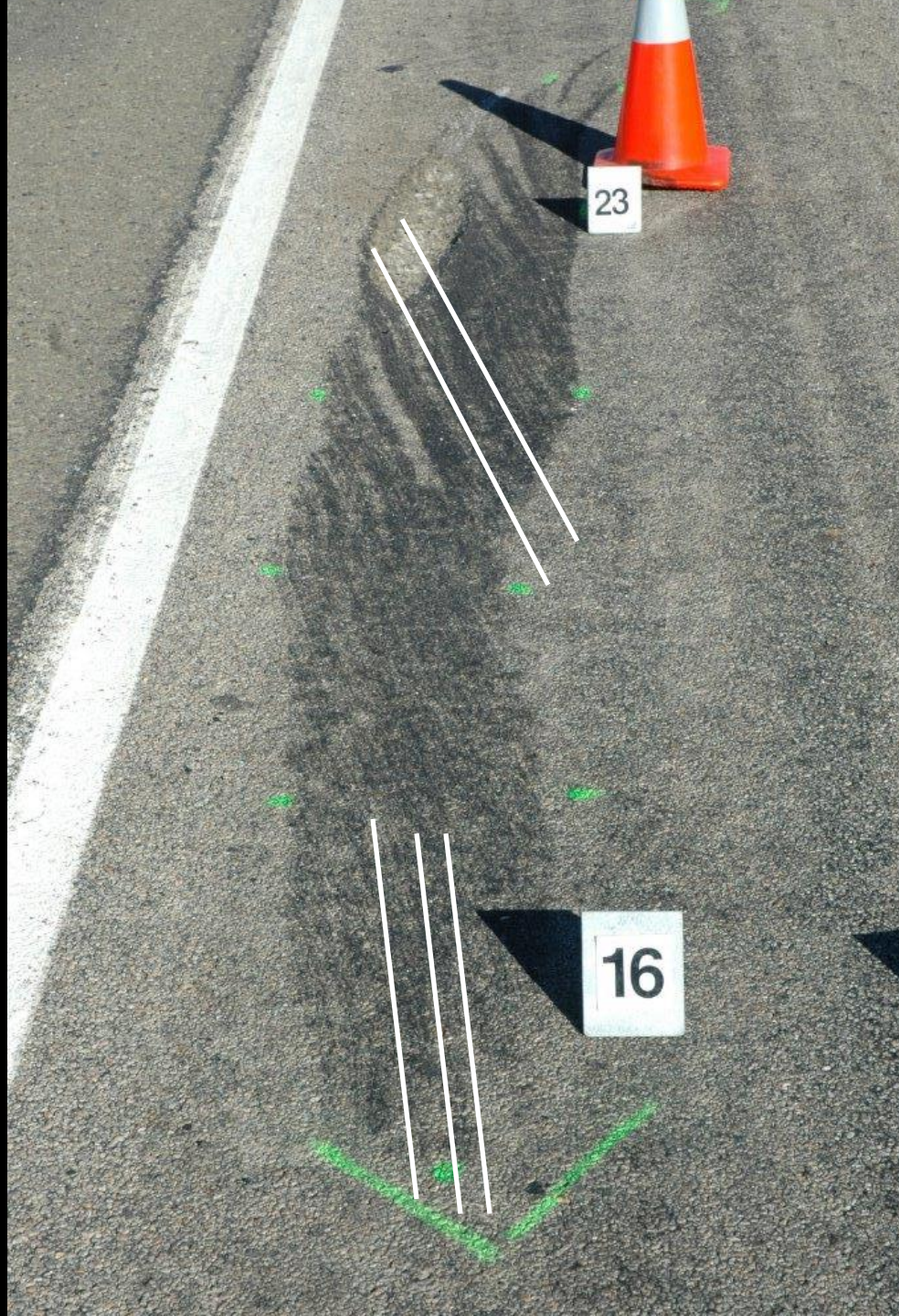
“Project Y.A.M. (Yaw Analysis Methodology)”

CSY will often produce an error in speed during a double-steer maneuver and should not be used.

This is not a CSY – too short.







SPIN

CAVEATS

ROAD DEFECT (causes yaw)

ROAD DESIGN (sudden weight shift)

MULTIPLE SURFACES

ARTICULATED VEHICLES

YAW CAUSED BY IMPACT



CAUSATION



Was the yaw caused by a
road defect?



“Velocity estimates using the speed from yaw marks equation should *never* be used to estimate after-collision velocities.”

Fricke, p. 72-31





***MECHANICAL
FAILURE AS
CAUSATION***





“I WAS BEHIND HIM.”

“HE HAD MOVED INTO THE
TURN LANE AND HAD
SLOWED DOWN TO TURN.”

“THE TRUCK SUDDENLY
FLIPPED OVER.”

TRUCKS WERE BUILT
WITH INCORRECT REAR
BRAKE ASSEMBLIES.

CONSEQUENCE OF DEFECT:

A TENDENCY FOR REAR BRAKE LOCKUP
EXISTS, PARTICULARLY WITH A LIGHTLY
LOADED TRUCK.

CHECK FOR
RECALLS
ON ALL VEHICLES !

www.nhtsa.gov

Check to see if
a recall has been repaired

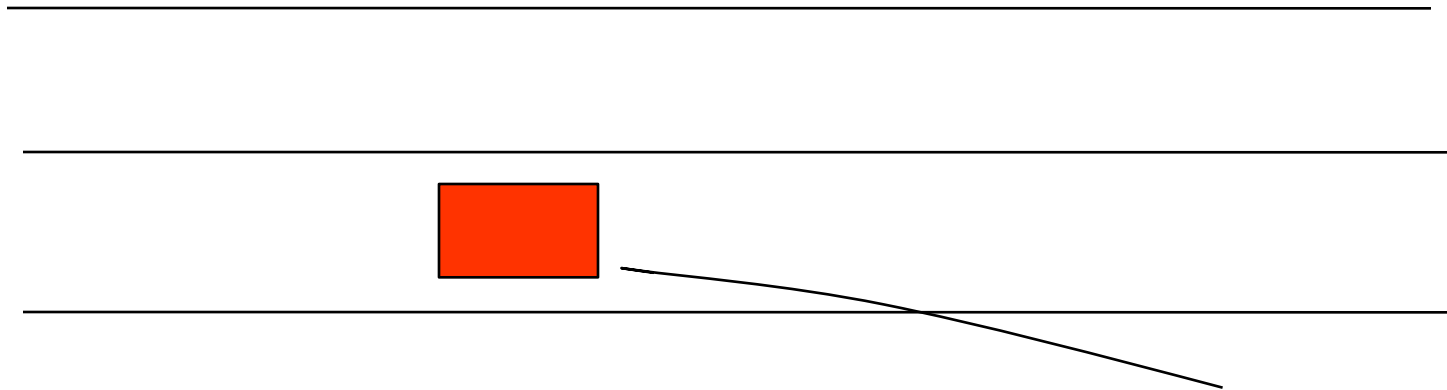
CHECK FOR
TSB's
***(TECHNICAL SERVICE
BULLETINS)***

www.nhtsa.gov

CHECK FOR
COMPLAINTS

www.nhtsa.gov

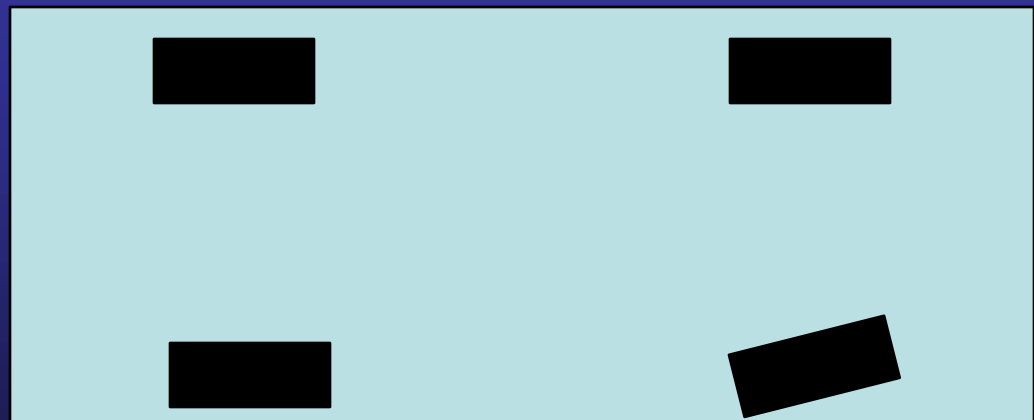
VEHICLE SUDDENLY STEERS TO
RIGHT, COLLIDES WITH GUARDRAIL.







RF WHEEL
TOED IN



NHTSA complaint file:

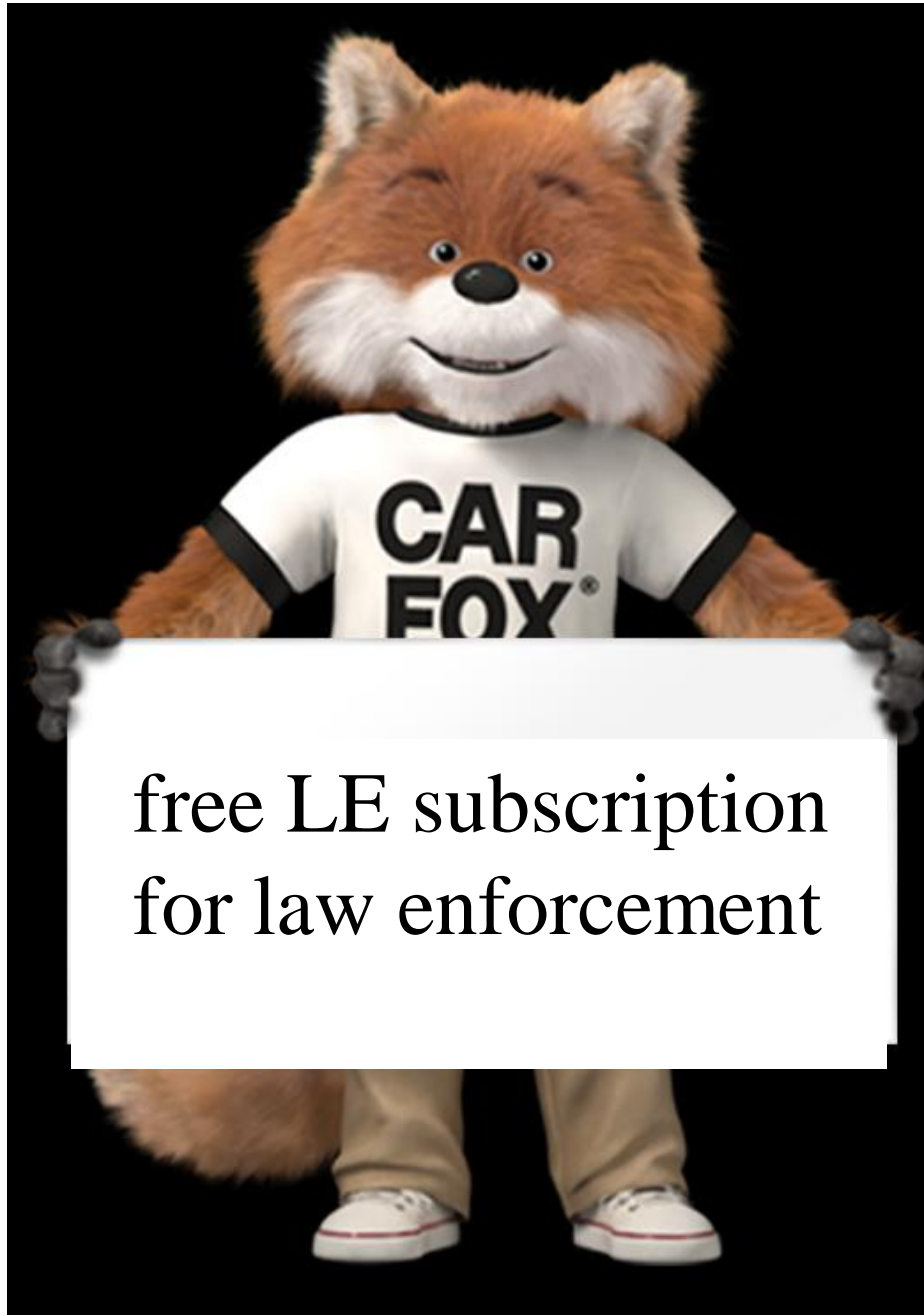
- 845 complaints filed by owners of this vehicle
- More than 70 include language like:
“when driving, right front wheel completely turned in”

NHTSA complaint file:

- 845 complaints filed by owners of this vehicle
- More than 70 include language like:
 - ”when driving, right front wheel completely turned in”
 - “subframe assembly on right front had rotted away, control arm assembly had separated from subframe”

NHTSA complaint file:

- 845 complaints filed by owners of this vehicle
- More than 70 include language like:
 - ”when driving, right front wheel completely turned in”
 - “subframe assembly on right front had rotted away, control arm assembly had separated from subframe”
 - “right front tire was sideways, my mechanic said subframe had corroded”



free LE subscription
for law enforcement

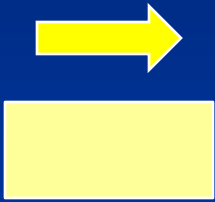
decodethis.com

enter VIN#

A DIFFERENT WAY TO LOOK
AT A SINGLE VEHICLE MOTION

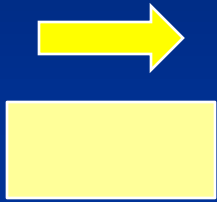
CONSERVATION OF ENERGY.

$$KE = .03376WS^2$$

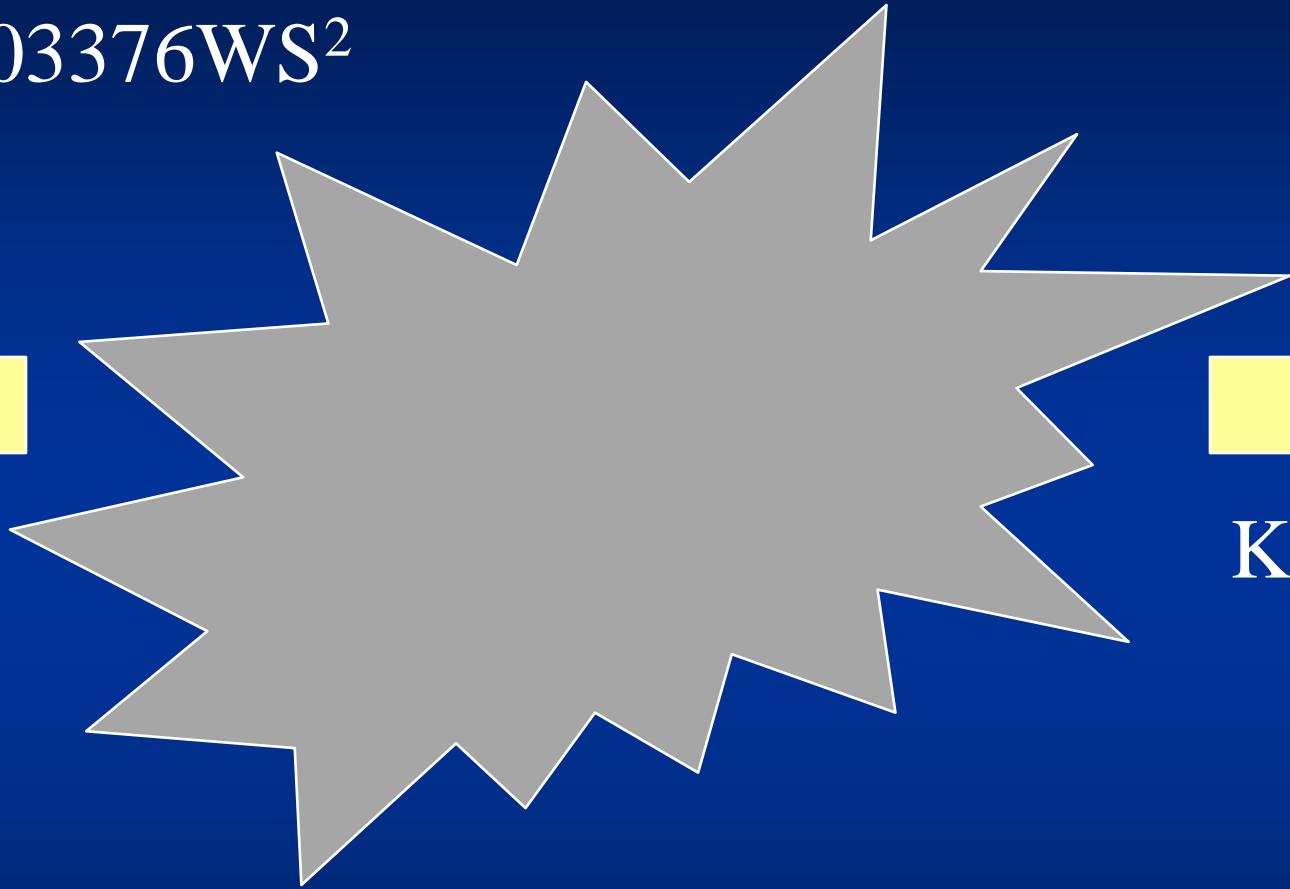
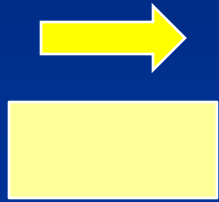


A VEHICLE IN MOTION HAS
KINETIC ENERGY

$$KE = .03376WS^2$$



$$KE = .03376WS^2$$



$$KE = 0$$

Conservation of Energy

The kinetic energy of a vehicle is changed to other forms during the collision, but the energy total is conserved.

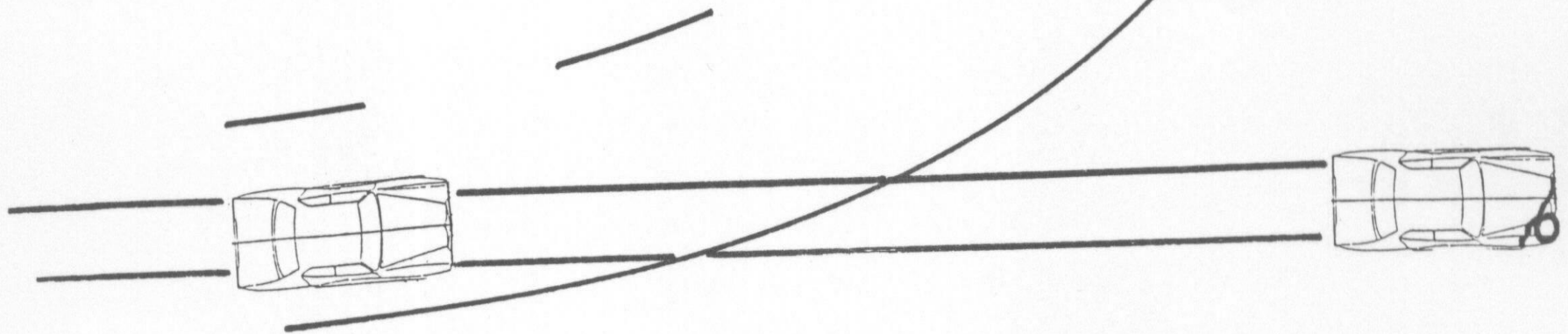
ENERGY ANALYSIS :

- IDENTIFY EACH ENERGY EVENT
- ISOLATE EACH EVENT
- DETERMINE AN ENERGY EQUIVALENT SPEED FOR EACH EVENT (EES)
- ADD THE SPEEDS

How did this
vehicle lose its
kinetic energy?



Speed estimate from energy:



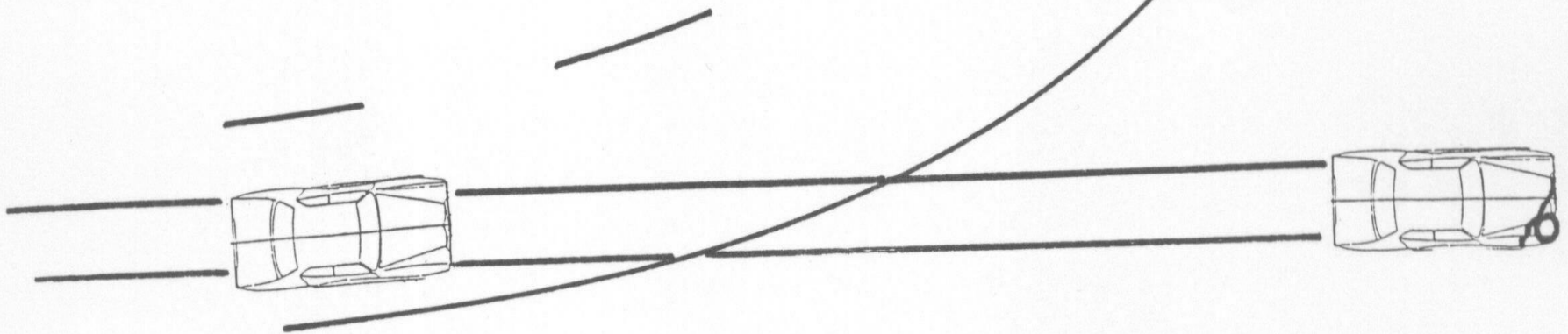
event #1

Skid/pavement

$$f = 0.78$$

$$d = 69 \text{ ft}$$

Speed estimate from energy:



event #2

Skid/pavement

$$f = 0.78$$

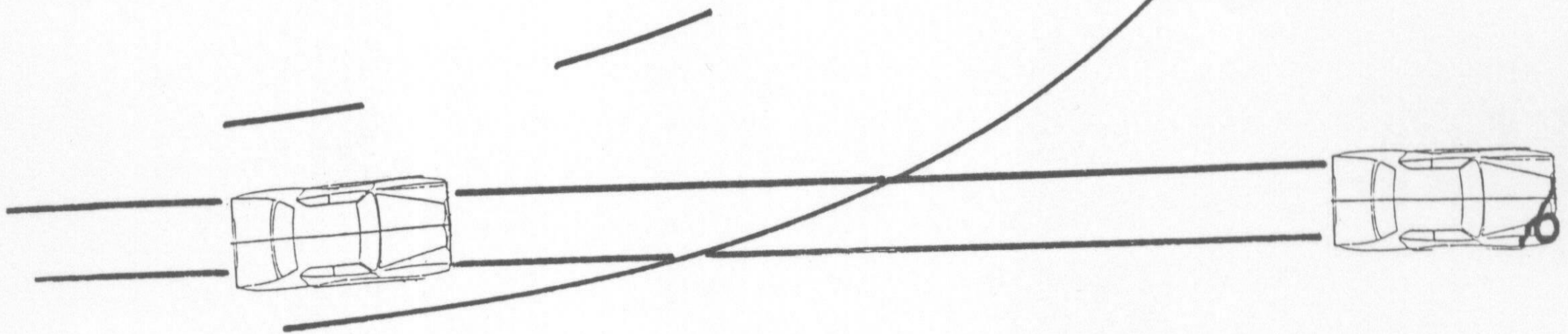
$$d = 69 \text{ ft}$$

Skid/grass

$$f = 0.5$$

$$d = 60 \text{ ft}$$

Speed estimate from energy:



event #3

Skid/pavement

$$f = 0.78$$

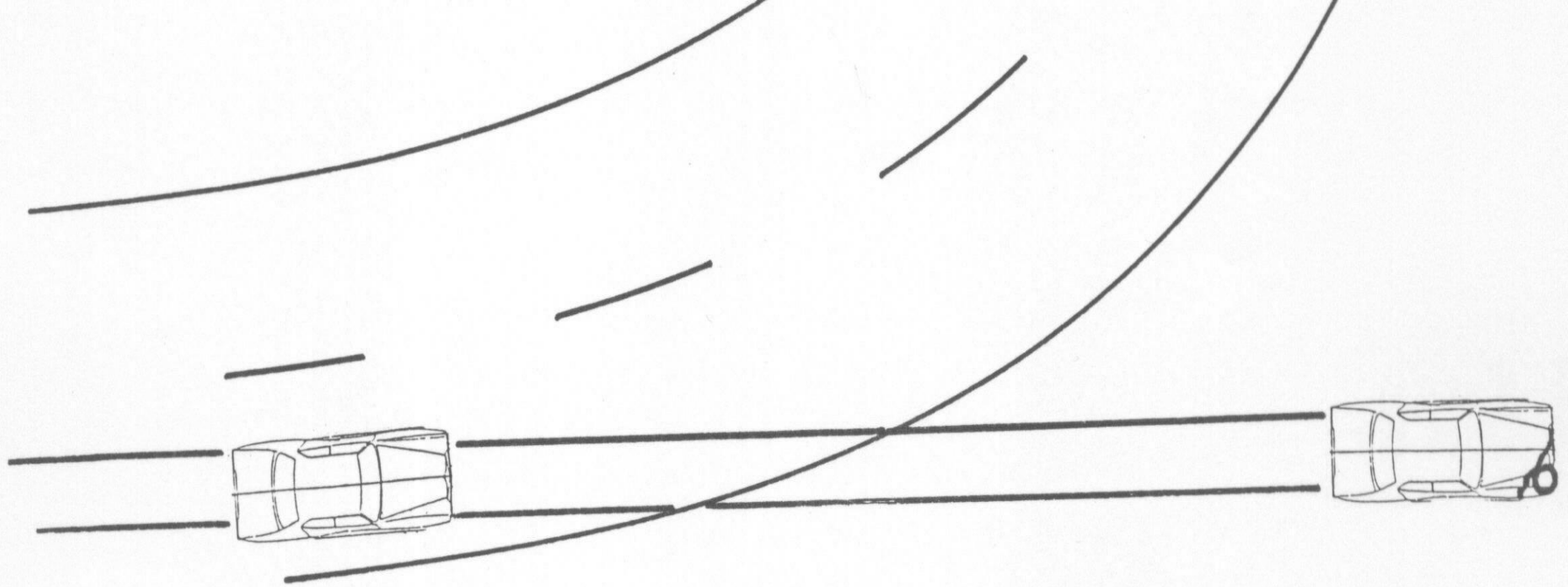
$$d = 69 \text{ ft}$$

Skid/grass

$$f = 0.5$$

$$d = 60 \text{ ft}$$

impact pole



Each event has an equivalent speed:

Skid/pavement

$$f = 0.78$$

$$d = 69 \text{ ft}$$

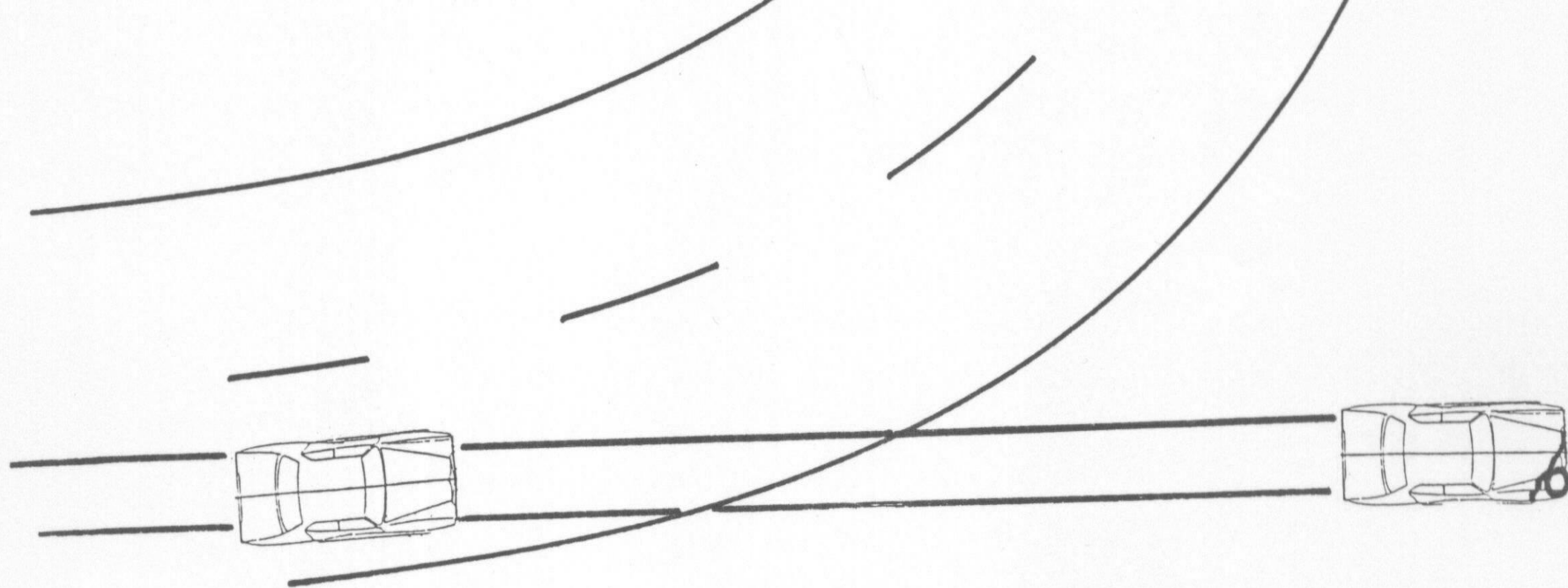
Skid/grass

$$f = 0.5$$

$$d = 60 \text{ ft}$$

impact pole

crush



40 mph



Skid/pavement

$f = 0.78$

$d = 69$ ft

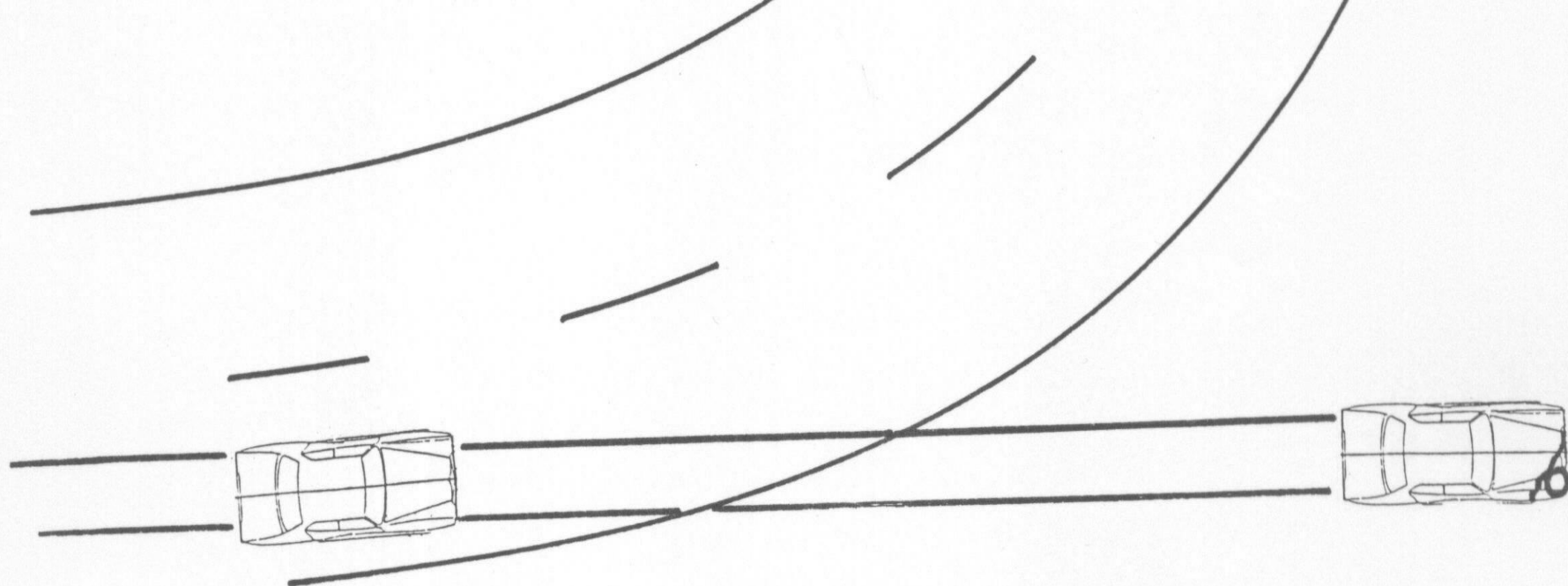
Skid/grass

$f = 0.5$

$d = 60$ ft

impact pole

35 mph



30 mph



Skid/pavement

$f = 0.78$

$d = 69 \text{ ft}$

Skid/grass

$f = 0.5$

$d = 60 \text{ ft}$

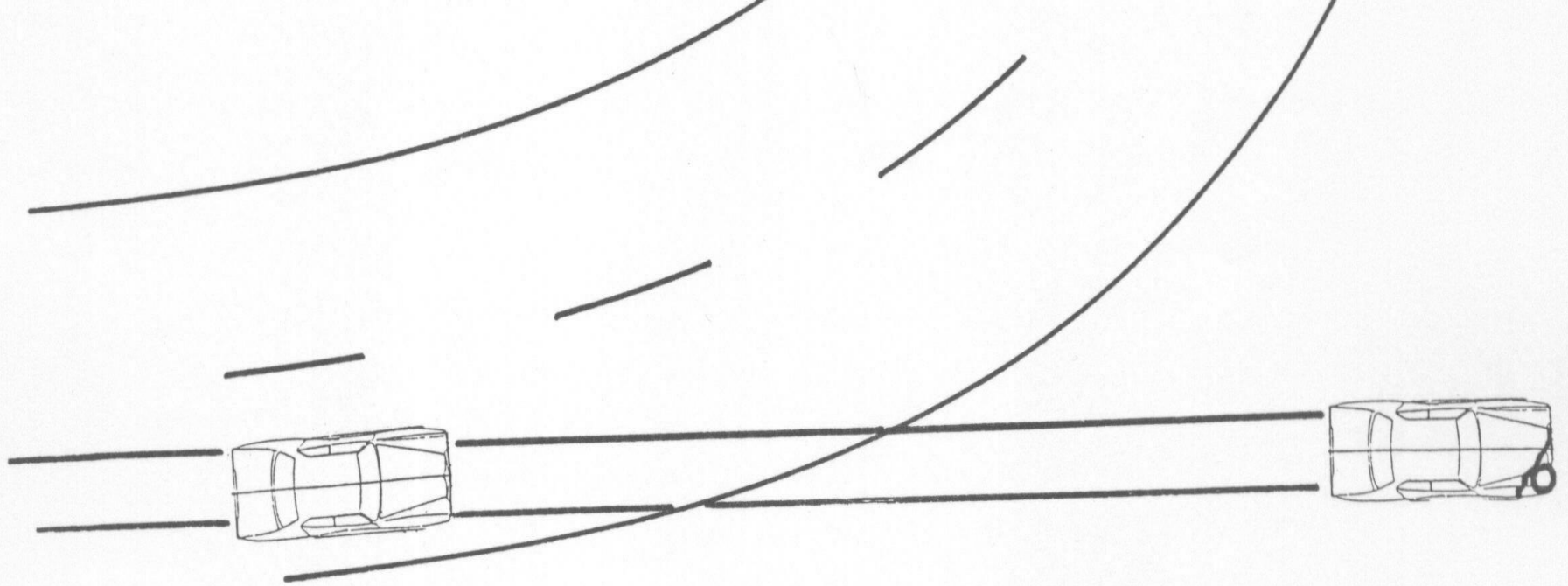
impact pole

CRUSH ANALYSIS

DAMAGE  EQUIV. SPEED





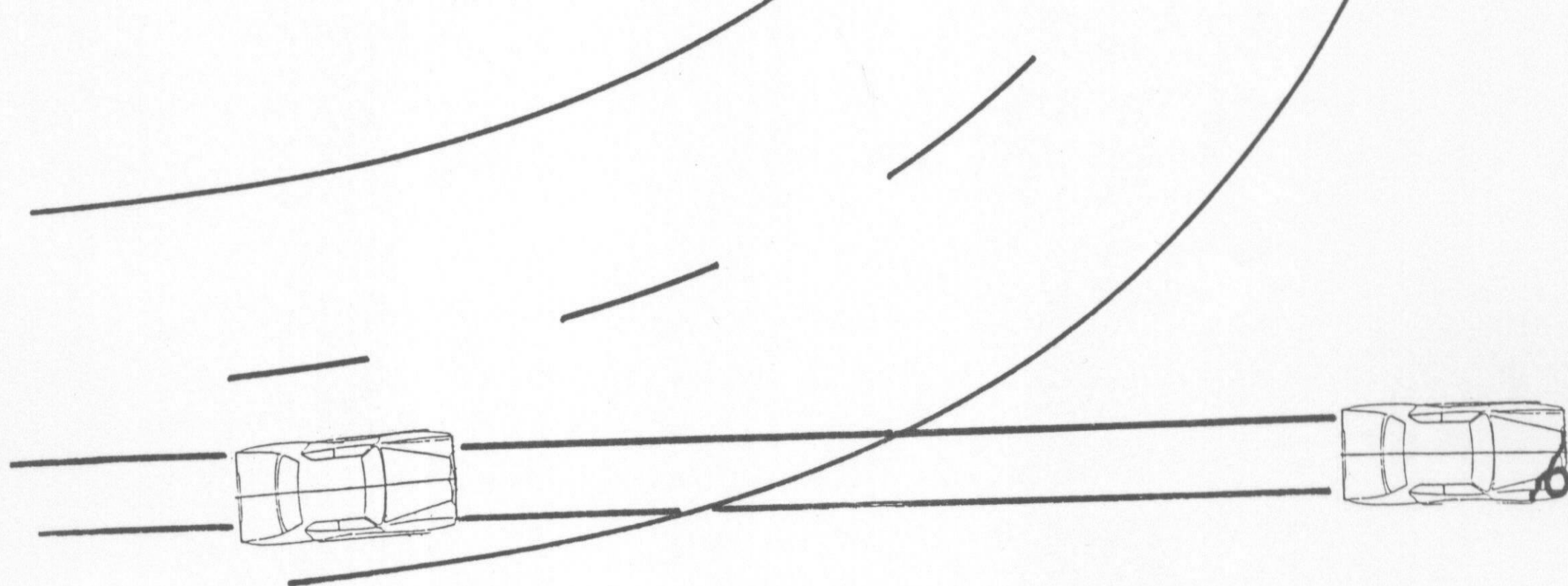


35 mph



impact pole

damage analysis
yields equivalent speed



40 mph



Skid/pavement

$f = 0.78$

$d = 69$ ft

30 mph



Skid/grass

$f = 0.5$

$d = 60$ ft

35 mph



impact pole

Combined Speeds Equation

$$S = \sqrt{S_1^2 + S_2^2 + S_3^2}$$

Combined Speeds Equation

$$S = \sqrt{40^2 + 30^2 + 35^2}$$

$$S = 61.0 \text{ mph}$$

A lesson I learned from a
defense lawyer in Salt Lake City