David L. Uhrich

The Perfect Case

Consider a 1976 Oldsmobile Cutlass (#2) which is northbound on Parkview Avenue. It stops for the stop sign at the T-intersection of Parkview Avenue with Portage street. It then pulls out onto Portage Street in a left turn. At about the time the Cutlass had crossed into the westbound lane of Portage Street, it was struck in the front by an eastbound 1972 Lincoln Continental (#1) which left 87' of pre-impact skidmarks. After impact the Cutlass rotated clockwise about its left rear and left marks off the north edge of Portage street with its front wheels and ended up pointing generally west in the westbound lane of Portage Street. It had completed nearly a 360° rotation and had traveled ~48' from impact to final rest. The Lincoln rotated counterclockwise about its left front after impact for 150° and ended up pointing northwest in the westbound lane. It traveled ~39' from impact to final rest,

The speed limit on Portage Street is 35 mph and at the time of the accident the pavement could be described as wet traveled asphalt. The Lincoln pre-impact skid of 87' occurred on a slight 3.5% downgrade going west to east.

There are several questions of interest in this accident. Of course, the natural one is how fast was the Lincoln going at the start of its pre-impact skid. Two additional questions of importance are:

1. Where was the Lincoln located west of impact when the Cutlass began to pull out? The importance of this question arises because there is a view obstruction for a northbound vehicle situated at the stop sign on Parkview Avenue. This obstruction arises because to the curvature of Portage Street west of the intersection, the slight grade and the trees et cetera south of the sidewalk on the south side of Portage Street.

2. If the Lincoln had been traveling at the speed limit limit of 35 mph at the time its driver first reacted to the presence of the Cutlass, where would it have stopped?

Analysis

I. Calculation of the speed of the Lincoln at the start of its pre-impact skid, This calculation requires several steps. They are: (1) Determination of the post-impact speed of the Cutlass at the start of its 48' travel after impact, (2) Determination of the post-impact speed of tne Lincoln at the start of its 39' travel after impact, (3) Determination of the pre-impact speed of the Cutlass, (4) A step across the collision via the principle of conservation of momentum to obtain the speed of tne Lincoln just before iapect, and (5) Determination of the pre-skid speed of the Lincoln.

a) Cutlass: post-impact speed.,

The Cutlass had three flat tires and did a near 360° rotation during its 48' post-impact travel. Most of the path was on wet asphalt and the front wheels slid sideways off the north berm for 22'. Here we consider the energy of motion possessed after impact dissipated in its slide to a stop.

$$V_{2A}^2 = 2 \mu_1 g d_2$$

$$d_2 = 48'$$

$$\mu_1 = 0.45 \to 0.70$$

$$g = 32.2 \text{ ft/sec}^2$$

Result: $V_{2A} = 25.4 \leftrightarrow 31.7$ mph

b) Cutlass: pre-impact speed.

The Cutlass stopped at the stop sign on Parkview Avenue. it then traveled from rest to impact in ~40' turn. If we assume normal to rapid acceleration for the turn, we can then compute its pre-impact speed.

$$d_1 = 40'$$

$$a = 4.8 \leftrightarrow 9.6 \text{ ft/sec}^2$$

$$d_1 = \tfrac{1}{2} a t_1^2 \implies t_1 = 2.9 \leftrightarrow 4.1 \text{ seconds}$$

$$V_{20} = a t_1 \implies V_{20} = 13.4 \leftrightarrow 19.0 \text{ mph}$$

iiote: If the collision were not a head-on collision, then one would need that component of the Cutlass' speed which was along the initial airection of the skidding Lincoln, The best case for the Lincoln would be for the Cutlass to have 0 speed in this direction, Later, we will compute the speed of the Lincoln at the start of its pre-impact skid for this limiting condition.

c) Lincoln: post-impact speed.

The Lincoln dissipated its energy of motion after impact by continuing a forward skid of approximately 20' as it began to rotate and slide for a total of 39' before stopping.

$$V_{1A}^2 = 2 \mu_1 g d_3$$

$$d_3 = 39'$$

$$\mu_1 = 0.45 \leftrightarrow 0.70$$

$$g = 32.2 \text{ ft/sec}^2$$

Result: $V_1 = 22.9 \leftrightarrow 28.6$ mph

d) Considering a one-dimensional or head-on collision, we may use conservation of momentum to obtain the pre-impact speed of the Lincoln.

$$m_1 V_{1O} + m_2 V_{2O} = m_1 V_{1A} + m_2 V_{2A}$$

$$V_{1A} = 22.9 \leftrightarrow 28.6 \text{ mph}$$

$$V_{2A} = 25.4 \leftrightarrow 31.7 \text{ mph}$$

$$V_{2O} = -(13.4 \leftrightarrow 19.0) \text{ mph}$$

$W_1 = m_1 g = 5219 + 250 = 5469$ lbs (Lincoln plus two people)

$W_2 = m_2 g = 3668 + 150 = 3818$ lbs (Cutlass + driver)

Result: $V_{1O} = 50.0 \leftrightarrow 64.0$ mph

Mote: If the pre-impact speed of the Cutlass along the pre-impact direction of the Lincoln was zero, then V_{20} in the above equation goes to zero and V_{10} = 40.6 - 53.8 mph.

e) Tne Lincoln's speed at the start of its pre-impact skid may be computed by considering that part of its initial energy of motion is dissipated in the 87' skid and the remainder is left over to cause the damage and post-impact motions,

$$V_{10}^2 = 2\mu_2 g d_4 + V_{10}^2$$

d_4 = 87'

g = 32.2 ft/sec²

μ = 0.415 ↔ 0.665 (0.45 ↔ 0.70 minus 0.035 to account for the 3.5% downgrade)

V_{10} = 50.0 ↔ 64.0 mph

Result: V_{10} = 59.8 ↔ 76.4 mph

Note: If the Cutlass' pre-speed along the Lincoln's skid direction is zero, then V_{10} = 52 - 68 mph.

II. Where was the Lincoln 0.8 seconds before the 87' pre-impact skid began? This distance can be compared to the stopping distance from 35 mpn whicn include the distance traveled in a 0.8 second reaction time and a skid to a stop.

a) Distance of the Lincoln from impact 0.8 seconds before its 87' pre-impact skid,

$$d_6 = (0.8)V_{10} + 87'$$

$$V_{10} = 59.8 \leftrightarrow 76.4 \text{ mph} = 87.7 \leftrightarrow 112.0 \text{ ft/sec}$$

Result: $d_6 = 157' \leftrightarrow 176'$

b) Stopping distance from 35 mph.

$$d_7 = 0.8\, V_3 + \frac{V_3^2}{2\mu_2 g}$$

$$V_3 = 35 \text{ mph } (51.3 \text{ ft/sec})$$

$$\mu_2 = 0.415 \leftrightarrow 0.665$$

$$g = 32.2 \text{ ft/sec}^2$$

Result: $d_7 = 103' \leftrightarrow 140'$

As a result, if the Lincoln had been traveling 35 mph at this time, it would have stopped before the impact occurred.

III. The distance of first sight to the west (of the impact point) for a northbound vehicle stopped at the stop sign on Parkview Avenue is 255'. Here, we will compute the time required for the Cutlass to make the turn, the time for the Lincoln's 87' pre-impact skid, subtract these two times and find out the location of the Lincoln when the Cutlass started its turn.

a) Time for the Cutlass' turn.

$$d_1 = \frac{1}{2} a t_1^2$$

$$d_1 = 40'$$

$$a = 4.8 \leftrightarrow 9.6 \text{ ft/sec}^2$$

Result: $t_1 = 2.9 \leftrightarrow 4.1$ seconds

b) Time for the Lincoln's 87' pre-impact skid.

$$t_2 = \frac{2\, d_4}{\bar{V}_{10} + V_{10}}$$

$$d_4 = 87'$$

$$V_{10} = 50.0 \leftrightarrow 64.0 \text{ mph}$$

$$\bar{V}_{10} = 59.8 \leftrightarrow 76.4 \text{ mph}$$

Result: $t_2 = 0.85 \leftrightarrow 1.08$ seconds

c) $t_1 - t_2 = 2.05 - 3.02$ seconds

iiote: Here, tne shorter (longer) times are consistent with the highest (lowest) pre-skid speed of the Lincoln and thus, must be subtracted.

a) Distance traveled by the Lincoln in 2.05 - 3.02 seconds prior to pre-impact skid.

$$d_5 = \bar{V}_{10}\,(t_1 - t_2)$$

$$\bar{V}_{10} = 59.8 \leftrightarrow 76.4 \text{ mph } (87.7 \leftrightarrow 112.0 \text{ ft/sec})$$

Result: $d_5 = 229' \leftrightarrow 264'$ {the shorter time goes with the higher speed}

e) Thus, the location of the Lincoln west of impact at the time when the Cutlass started its turn is:

$d_5 + 87' = 316' - 351'$ (west)

Note: The distance of first sight west of the impact point is 255'. Thus, the Lincoln was not visible to the driver of the Cutlass when he started his turn.

Conclusions

1. The speed of the Lincoln at the start of its pre-impact skid was 25 - 40 mph above the 35 mph speed limit.
2. If the Lincoln had been traveling 35 mph when its driver reacted to the Cutlass, it could have stopped short of impact,
3. The Lincoln was not within the line of sight of the driver of the Cutlass when he began his turn.

TRAFFIC CRASH REPORT 499-5911 OH-1 (Rev. 1/77)

LOCAL REPORT NO.		CITY CODE	— DEPT. OF HIGHWAY SAFETY ONLY —	ACCIDENT SEVERITY
594	[ ] OH-2 [X] OH-3 [X] OH-5			[ ] FATAL [X] INJURY [X] PROP. DAMAGE [ ] P.D. UNDER $150 [ ] ON PRIV. PROP.

FILE NO. LOCAL USE: 594

REPORTING AGENCY	OH	TIME OF CRASH	DAY	DATE OF CRASH
NORTH CANTON POLICE DEPT.	07611	0248	WED.	02 (MO.) 24 (DAY) 80 (YR.)

IN COUNTY OF	ON ROUTE, CO. OR TWP. ROAD, STREET ADDRESS	AT JUNCTION OR INTERSECTION WITH	
STARK	700 BLK PORTAGE ST., N.W.	—	[ ] HIT & RUN UNSOLVED [ ] HIT & RUN SOLVED

IN (CITY, VILLAGE, TOWNSHIP) OF			OF	MILEPOST, JUNCTION, INTERSECTION, BRIDGE, ETC.	PHOTO REFERENCE
NORTH CANTON	10' [ ] MILES [X] FEET	N S E (W)	OF	PARKVIEW AVE. N.W.	867

FED AID	LOG-LOC	JUR	TC	FLT	DESCRIPTION	DIR. ALIGN

UNIT NO. 1

TOTAL UNITS INVOLVED: 2

DRIVER — LAST	FIRST	MIDDLE	SEX	DATE OF BIRTH	AGE	SOCIAL SECURITY NUMBER
[redacted]	DALE	A	M	06 (MO.) 16 (DAY) 58 (YR.)	22	274 60 5283

ADDRESS — NUMBER STREET	CITY	STATE	PHONE	CIRCLE DAMAGED AREAS
[redacted] RALEIGH Dr.	MASSILLON,	OHIO 44646	833-9573	

STATE	OPERATOR LIC. NO.	RESTR	CLASS	ENDOR	OCCUPATION	DAMAGE SEVERITY
OHIO	NJ335307	—	1	—	H & F AUTO Supply, CANTON	SL [ ] MO [ ] [ ] SE [X] DE

OWNER — LAST	FIRST	MIDDLE	ADDRESS — NUMBER STREET	CITY	STATE	PHONE
SAME			SAME			833-9573

VEHICLE YEAR	MAKE	MODEL NAME	COLOR	BODY STYLE	VEHICLE DIR.	ODOMETER READING	STATE	LICENSE NO.	YEAR
19 72	LINCOLN	CONTINENTAL	Brown	2D	N S (E) W	91,020	OHIO	ERL 372	80

NAME OF INSURANCE COMPANY/AGENT	NAME OF WRECKER	INJURED TAKEN TO	BY WHOM
NONE	NORTHWEST	AULTMAN	N. CANTON EMS

DAMAGE ESTIMATE	ALCOHOL TEST GIVEN	TYPE	RESULTS	ORD. OR CODE NUMBER	ORD. DESCRIPTION
NONE [ ] OVER $150 [X] UNDER $150 [ ]	[X] NO [ ] YES			[X] CITY ORD. 3655 [ ] STATE CODE Sect 333-03	RECKLESS OPERATION

UNIT NO. 2

DRIVER — LAST	FIRST	MIDDLE	SEX	DATE OF BIRTH	AGE	SOCIAL SECURITY NUMBER
[redacted]	JAMES	F	M	07 (MO.) 28 (DAY) 51 (YR.)	29	276 50 5684

ADDRESS — NUMBER STREET	CITY	STATE	PHONE	CIRCLE DAMAGED AREAS
[redacted] STATE ST.	N. CANTON,	OHIO 44720	499-3616	

[X] VEH [ ] PED [ ] ANIMAL [ ] TRAIN

STATE	OPERATOR LIC. NO.	RESTR	CLASS	ENDOR	OCCUPATION	DAMAGE SEVERITY
OHIO	NG982882	—	1	—	KELLER ELECTRIC.	SL [ ] MO [ ] [ ] SE [X] DE

OWNER — LAST	FIRST	MIDDLE	ADDRESS — NUMBER STREET	CITY	STATE	PHONE
SAME			SAME			499-3616

PROPERTY: CITY [ ] COUNTY [ ] STATE [ ] FEDERAL [ ] PRIVATE [ ]

VEHICLE YEAR	MAKE	MODEL NAME	COLOR	BODY STYLE	VEHICLE DIR.	ODOMETER READING	STATE	LICENSE NO.	YEAR
19 76	OLDSMOBILE	CUTLASS SUPREME	White	2D	N S E (W)	16,855	OHIO	LAN 038	80

NAME OF INSURANCE COMPANY/AGENT	NAME OF WRECKER	INJURED TAKEN TO	BY WHOM
NATIONWIDE	NORTHWEST	AULTMAN	GREENTOWN EMS

OWNER NOTIFIED: YES [ ] NO [ ]

DAMAGE ESTIMATE	ALCOHOL TEST GIVEN	TYPE	RESULTS	ORD. OR CODE NUMBER	ORD. DESCRIPTION
NONE [ ] OVER $150 [X] UNDER $150 [ ]	[X] NO [ ] YES			[X] CITY ORD. 3658 [ ] STATE CODE Sect 331.17	... WHEN TURNING LEFT

OCCUPANTS

OCC. UNIT	NAME — LAST	FIRST	MIDDLE	DATE OF BIRTH	AGE
1/1	[redacted]	JUDY	E.	07 (MO.) 14 (DAY) 47 (YR.)	33

ADDRESS — NUMBER STREET	CITY	STATE	PHONE	SEX
[redacted] RALEIGH Dr.	MASSILLON, OHIO	44646	833-9573	F

OCC. 2, OCC. 3, OCC. 4: NAME — LAST / FIRST / MIDDLE / DATE OF BIRTH MO. DAY YR. / AGE / ADDRESS — NUMBER STREET / CITY / STATE / PHONE / SEX (crossed out)

TIME POLICE	RECEIVED CALL	DISPATCHED	ARRIVED SCENE	CLEARED SCENE	OTHER INVESTIGATION	TOTAL TIME
	0248	0248	0249	0432	4 hr	6 hours

OCC.	INJURED TAKEN TO	BY WHOM	INJURED TAKEN TO	BY WHOM	OFFICER'S I.D.
1	AULTMAN	N. CANTON EMS	—	—	01-32
2	—	—	OCC. 4 —		CHECKED BY 71-16

		DR. 1	DR./PED 2	OCCUPANT 1	2	3	4
INJURY SEVERITY							
Fatal	1						
Incapacitating injury	2						
Visible signs of injury	3	X	X	X			
Claimed injury	4						
No claimed injury	5						
RESTRAINTS IN USE							
Seat belt	1						
Harness and seat belt	2						
Shoulder harness	3						
None in use	4	X	X	X			
Other	5						
None installed	6						
POSITION							
Front left	1	X	X				
Front center	2						
Front right	3			X			
Back left	4						
Back center	5						
Back right	6						
Other	7						
CONDITION (PED/DR)							
Apparently normal	1						
Sick	2						
Fatigued	3						
Apparently sleepy	4						
Physical defect	5						
Apparently drinking	6	X	X	X			
OMVI	7						
Apparent drug usage	8						
EJECTION							
Total	1						
Partial	2						
Not ejected	3	X	X	X			
Trapped	4						

1

TYPE OF CRASH

Two Moving Motor Vehicles)
- 01 [X] Head-on
- 02 [ ] Rear-end
- 03 [ ] Sideswipe
- 04 [ ] Angle
- 05 [ ] Turning

(One Moving MV and —)
- 06 [ ] Parked motor vehicle
- 07 [ ] Pedestrian
- 08 [ ] Animal
- 09 [ ] Train
- 10 [ ] Pedalcycles
- 11 [ ] Other non-motor vehicle
- 12 [ ] Fixed object
- 13 [ ] Other object

(One MV Only)
- 14 [ ] Overturning
- 15 [ ] Other non-collision

MOTORCYCLE (crossed out)

UNIT 1 2
- 1 [ ] [ ] Light (up to 100 cc)
- 2 [ ] [ ] Medium (101 to 349 cc)
- 3 [ ] [ ] Heavy (over 350 cc)
- 4 [ ] [ ] Yes — Helmet
- 5 [ ] [ ] No
- 6 [ ] [ ] Yes — Extended fork
- 7 [ ] [ ] No

- 1 [ ] Street or highway intersection
- 2 [X] Intersection related
- 3 [ ] Driveway access
- 4 [ ] Railroad crossing
- 5 [ ] Bridge (over 20' span)
- 6 [ ] Subway (underpass)
- 7 [ ] Bridge or culvert (spans 20 and under)
- 8 [ ] Interchange
- 9 [ ] Non-intersection

CONTOUR
- 1 [X] Straight, level
- 2 [ ] Straight, grade
- 3 [ ] Straight, hillcrest
- 4 [ ] Curve, level
- 5 [ ] Curve, grade
- 6 [ ] Curve, hillcrest

OCCURRENCE
- 1 [X] On roadway
- 2 [ ] Off roadway
- 3 [ ] Off left side
- 4 [ ] Off right side
- 5 [ ] On other roadway (divided highway)

RAMP (crossed out)

Lettercode ______
- 1 [ ] Ramp beginning
- 2 [ ] On the ramp
- 3 [ ] Ramp end
- 4 [ ] At the intersection of two ramps

- 1 [ ] Daylight
- 2 [ ] Dawn or dusk
- 3 [X] Dark—no lights
- 4 [ ] Dark but lighted
- 5 [ ] Other ______

CAUSATIVE FACTORS

UNIT 1 2
- 01 [ ] [X] Failure to yield
- 02 [ ] [ ] Ran stop signal
- 03 [ ] [ ] Driving wrong way
- 04 [ ] [ ] Improper passing
- 05 [ ] [ ] Improper turning
- 06 [ ] [ ] OMVI
- 07 [ ] [ ] Driving too slow
- 08 [ ] [ ] Traffic signal violation
- 09 [X] [ ] Left of center
- 10 [ ] [ ] Stopped or parked illegally
- 11 [X] [ ] Excessive speed
- 12 [ ] [ ] Following too close
- 13 [X] [X] Driver inattention
- 14 [ ] [ ] View obstruction
- 15 [ ] [ ] None
- 16 [ ] [ ] Vehicle defects
- 17 [ ] [ ] Road defects
- 18 [ ] [ ] Ped. action
- 19 [ ] [ ] Other ______

DEFECTS

UNIT 1 2
- 1 [ ] [ ] Brakes
- 2 [ ] [ ] Lights
- 3 [ ] [ ] Steering
- 4 [ ] [ ] Tires
- 5 [ ] [ ] Other ______
- 6 [X] [X] None

- 1 [X] No adverse weather condition
- 2 [ ] Rain
- 3 [ ] Snow
- 4 [ ] Fog
- 5 [ ] Heavy wind
- 6 [ ] Other ______

PEDESTRIAN ACTION (crossed out)
- 01 [ ] In crosswalk
- 02 [ ] Crossing other than crosswalk
- 03 [ ] Walking with traffic
- 04 [ ] Walking against traffic
- 05 [ ] Working or playing in roadway
- 06 [ ] Entering or leaving vehicle
- 07 [ ] On highway but not in roadway
- 08 [ ] Off highway
- 09 [ ] Other
- 10 [ ] Working on car

FIXED ROADSIDE OBJECTS STRUCK

UNIT 1 2
- 1 [ ] [ ] Light or utility pole
- 2 [ ] [ ] Bridge or culvert
- 3 [ ] [ ] Sign, signal or support
- 4 [ ] [ ] Guard rail
- 5 [ ] [ ] Fence
- 6 [ ] [ ] Tree
- 7 [ ] [ ] Ditch or embankment
- 8 [ ] [ ] Curb
- 9 [ ] [ ] Construct barricade
- 0 [X] [ ] None
- 11 [ ] [ ] Other ______

- 1 [ ] Dry
- 2 [X] Wet
- 3 [ ] Snow or ice
- 4 [ ] Mud or sand
- 5 [ ] Other ______

NO. LANES 2

INTENDED DRIVER ACTION

UNIT 1 2
- 01 [X] [ ] Going straight
- 02 [ ] [ ] Changing lanes
- 03 [ ] [ ] Passing
- 04 [ ] [ ] Turning right
- 05 [ ] [X] Turning left
- 06 [ ] [ ] Stopped to turn
- 07 [ ] [ ] Parking
- 08 [ ] [ ] Unparking
- 09 [ ] [ ] Parked
- 10 [ ] [ ] Backing
- 11 [ ] [ ] Stopped in traffic
- 12 [ ] [ ] U-turn
- 13 [ ] [ ] Merging onto freeway
- 14 [ ] [ ] Exiting from freeway
- 15 [ ] [ ] Swerving to avoid
- 16 [ ] [ ] Other ______

TRAFFIC CONTROL

UNIT 1 2
- 1 [ ] [ ] Traffic officer
- 2 [ ] [X] Stop sign (PARKVIEW)
- 3 [ ] [ ] Yield sign
- 4 [ ] [ ] Railroad signal
- 5 [ ] [ ] Traffic signal
- 6 [ ] [ ] Official barricade
- 7 [ ] [ ] Other ______
- 8 [X] [ ] None

- 1 [X] Asphalt
- 2 [ ] Concrete
- 3 [ ] Gravel
- 4 [ ] Other ______

ROAD WIDTH 24'

TYPE OF UNIT

UNIT 1 2
- 01 [X] [X] Passenger car
- 02 [ ] [ ] Single body truck
- 03 [ ] [ ] Pickup
- 04 [ ] [ ] Van
- 05 [ ] [ ] Truck Tractor
- 06 [ ] [ ] Tractor/Semi-Trailer
- 07 [ ] [ ] Tractor/Double Trailer
- 08 [ ] [ ] Fire truck
- 09 [ ] [ ] Police vehicle
- 10 [ ] [ ] Emergency vehicle
- 11 [ ] [ ] Bus public
- 12 [ ] [ ] Bus school
- 13 [ ] [ ] Bus church
- 14 [ ] [ ] Taxi
- 15 [ ] [ ] Train
- 16 [ ] [ ] Motorcycle
- 17 [ ] [ ] Motor scooter
- 18 [ ] [ ] Motor home
- 19 [ ] [ ] Bicycle
- 20 [ ] [ ] Motorized bicycle
- 21 [ ] [ ] Animal w/rider
- 22 [ ] [ ] Animal w/buggy
- 23 [ ] [ ] Farm veh., unlicensed
- 24 [ ] [ ] Other ______

TOWING (crossed out)

UNIT 1 2
- 01 [ ] [ ] Trailer
- 02 [ ] [ ] Camper
- 03 [ ] [ ] Other ______

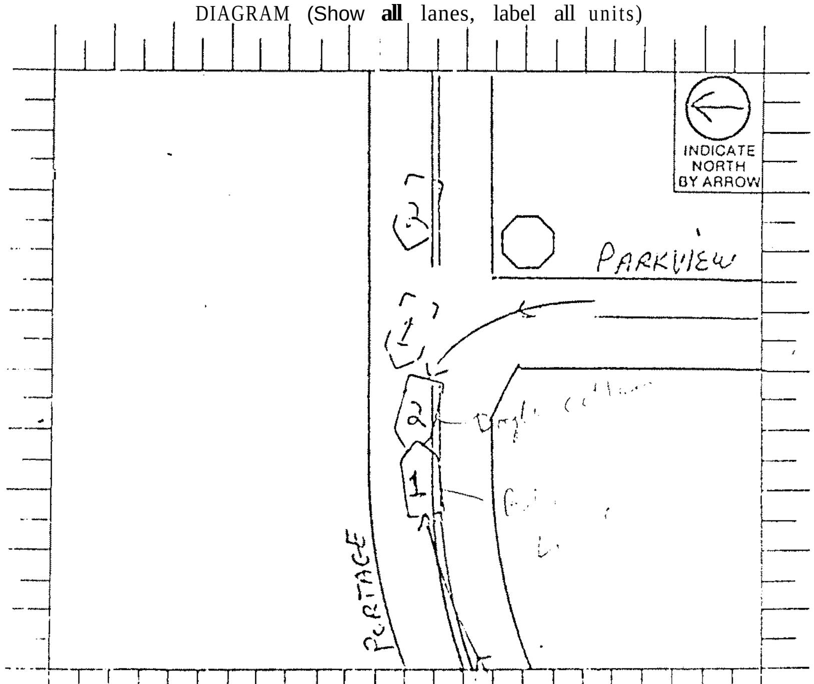
ACCIDENT DESCRIPTION TO INCLUDE POINT OF IMPACT:

VEHICLE #1 WAS EASTBOUND ON PORTAGE ST. N.W & WENT LEFT OF CENTER INTO THE WESTBOUND LANE & COLLIDED WITH VEHICLE #2. VEHICLE #2 STOPPED ON PARKVIEW N.W AT PORTAGE ST. N.W, THEN PROCEEDED TO TURN LEFT (WESTBOUND) ONTO PORTAGE ST. IN DOING SO, OPERATOR OF VEHICLE #2 FAILED TO SEE & YIELD THE RIGHT OF WAY TO ONCOMING TRAFFIC ON PORTAGE ST., THEREBY COLLIDING WITH VEHICLE #1.

— OTHER INVESTIGATION NOTES —

AT THE ACCIDENT SCENE, BOTH DRIVERS STATED THEY HAD BEEN DRINKING PRIOR TO THE CRASH.

DIAGRAM (Show all lanes, label all units)



NOT DRAWN TO SCALE SEE CH-2

SPEED			SKIDMARK DATA		
UNIT	STATED	POSTED		UNIT 1	UNIT 2
			R.F.		
			L.F.		
1	35-40	35	R.R.		
2	10-15	35	L.R.		
			% Gr		

Ohio

TRAFFIC CRASH REPORT ADDENDUM

LOCAL REPORT NO. 594

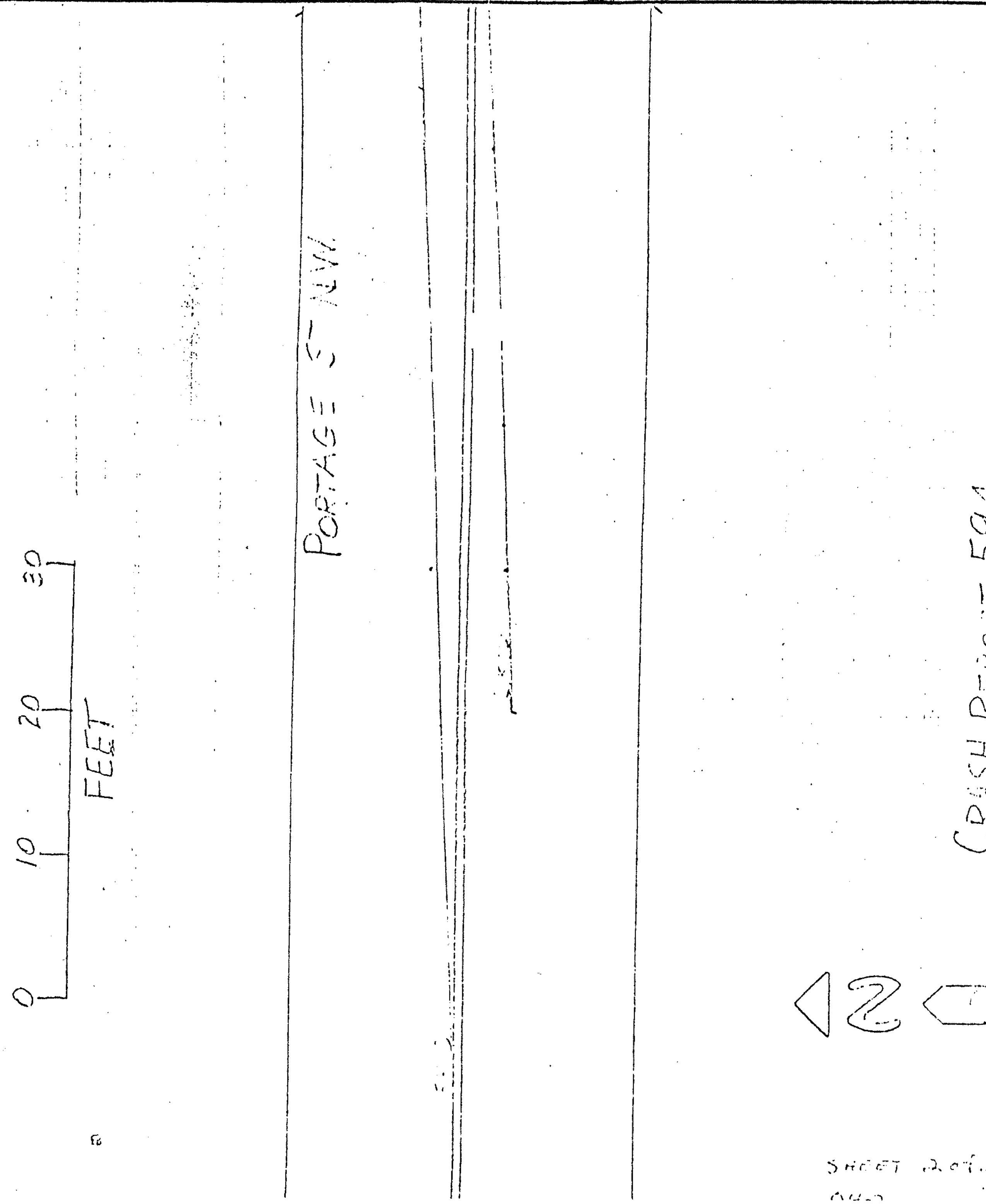
STATE USE ONLY

REPORTING AGENCY	TIME OF CRASH	DATE OF CRASH	
NORTH CANTON POLICE DEPT. OH 07611	2:48 ☒ A.M. ☐ P.M.	12 MO. 24 DAY 80 YR.	O FATALITY ☐ INJURY

CRASH OCCURRED IN (CITY, VILLAGE, TOWNSHIP)	IN COUNTY OF
NORTH CANTON	STARK

STATE ROUTE, CO. OR TWP. ROAD, STREET ADDRESS		AT JUNCTION OR INTERSECTION WITH
700 BLK PORTAGE ST. N.W.	OT ☐ CS ☐ IS ☐ US ☐ SR ☐ CR ☐ TR ☐ PR ☐ TP ☐	—

UNIT	DRIVER — LAST	FIRST	MIDDLE	UNIT	DRIVER — LAST	FIRST	MIDDLE
#1	[redacted]	DALE	A	#2	[redacted]	JAMES	F



CRASH REPORT 594
12/24/80 0248 HRS

SHEET 2 of 2

. of Ohio

TRAFFIC CRASH REPORT ADDENDUM

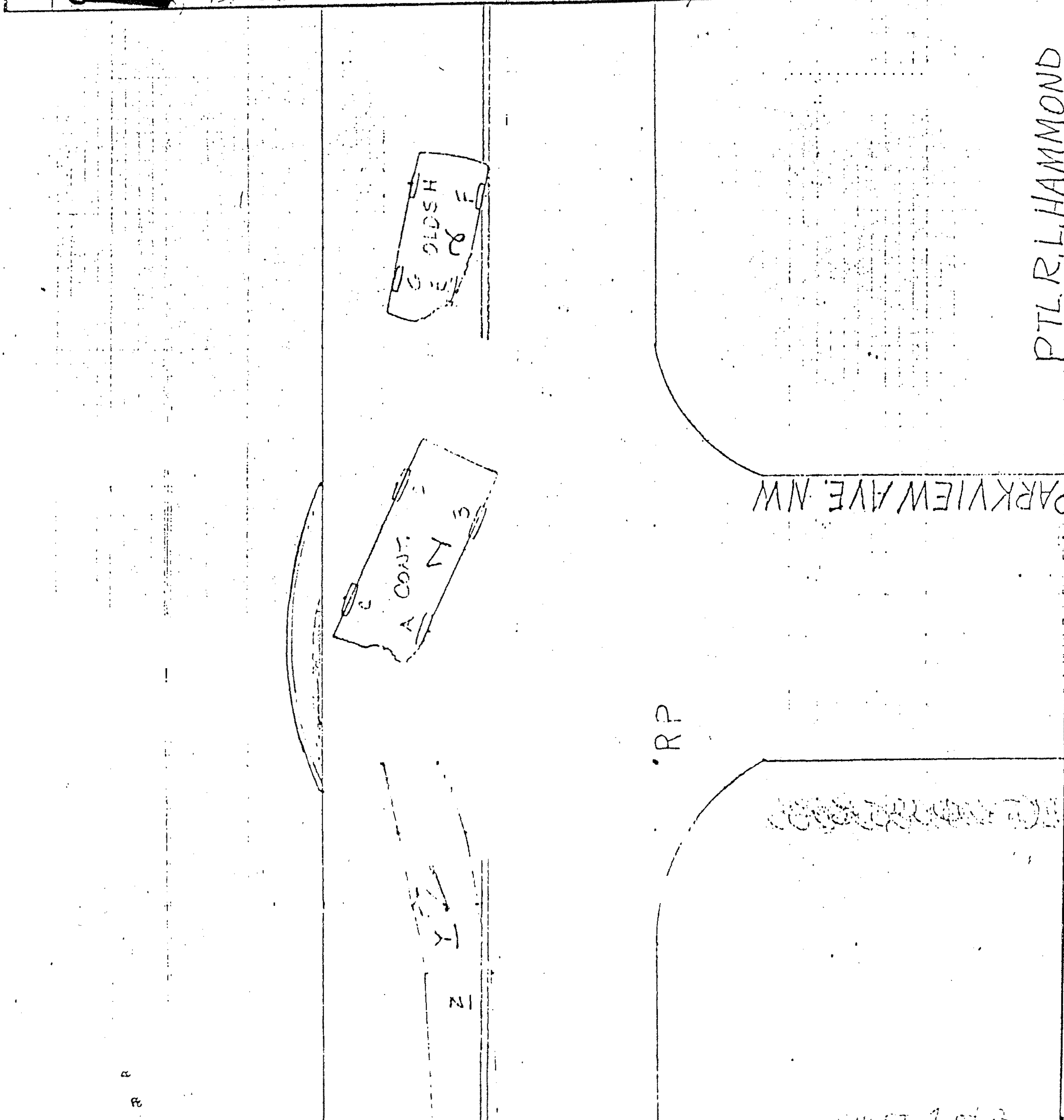
LOCAL REPORT NO. 594		STATE USE ONLY

REPORTING AGENCY	TIME OF CRASH	DATE OF CRASH (MO. / DAY / YR.)	
NORTH CANTON POLICE DEPT OH 07611	2:49 [x] A.M. [ ] P.M.	12 / 24 / 80	[ ] FATALITY [x] INJURY

CRASH OCCURRED IN (CITY, VILLAGE, TOWNSHIP)	IN COUNTY OF
NORTH CANTON	STARK

STATE ROUTE, CO. OR TWP. ROAD, STREET ADDRESS	OT CS IS US SR CR TR PR TP	AT JUNCTION OR INTERSECTION WITH
700 BLK PORTAGE ST. N.W.	[x] CS	—

UNIT	DRIVER — LAST	FIRST	MIDDLE	UNIT	DRIVER — LAST	FIRST	MIDDLE
#1	[redacted]	DALE	A	#2	[redacted]	JAMES	F

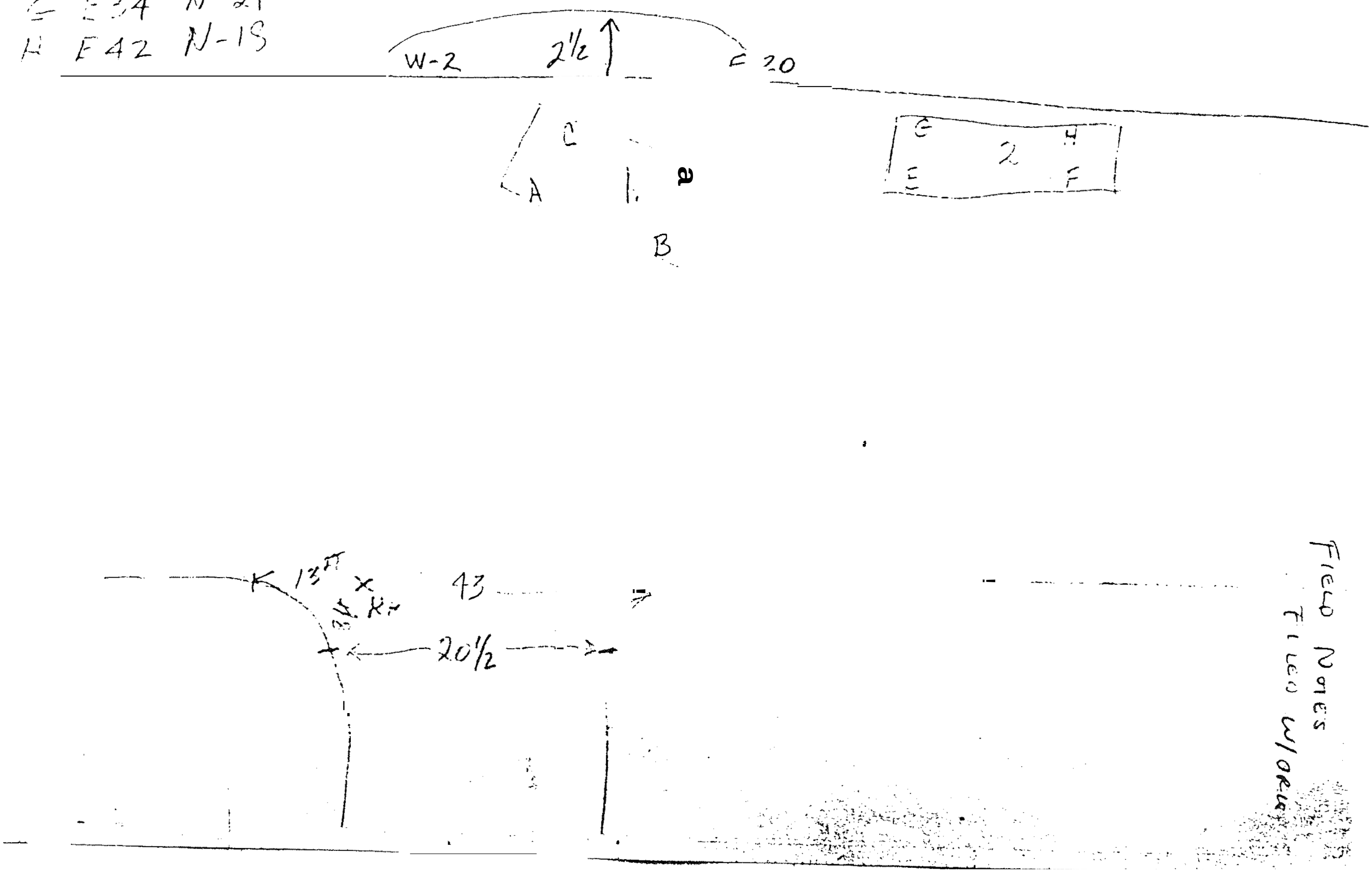


CRASH REPORT
594
12/24/80
R.L. Hammond

Tonage ...

A - E 9/6 N 16/6
B - E 17/6 N 12/6
C - E 12 N 22/9
D - E 20 N - 19

E E 33 N - 14/6
F E 41 N - 12/6
G E 34 N - 21
H E 42 N - 19



FIELD NOTES
FILED W/ORIG

CRASH REPORT 574
12/24/80

Center line 12 1/4 in

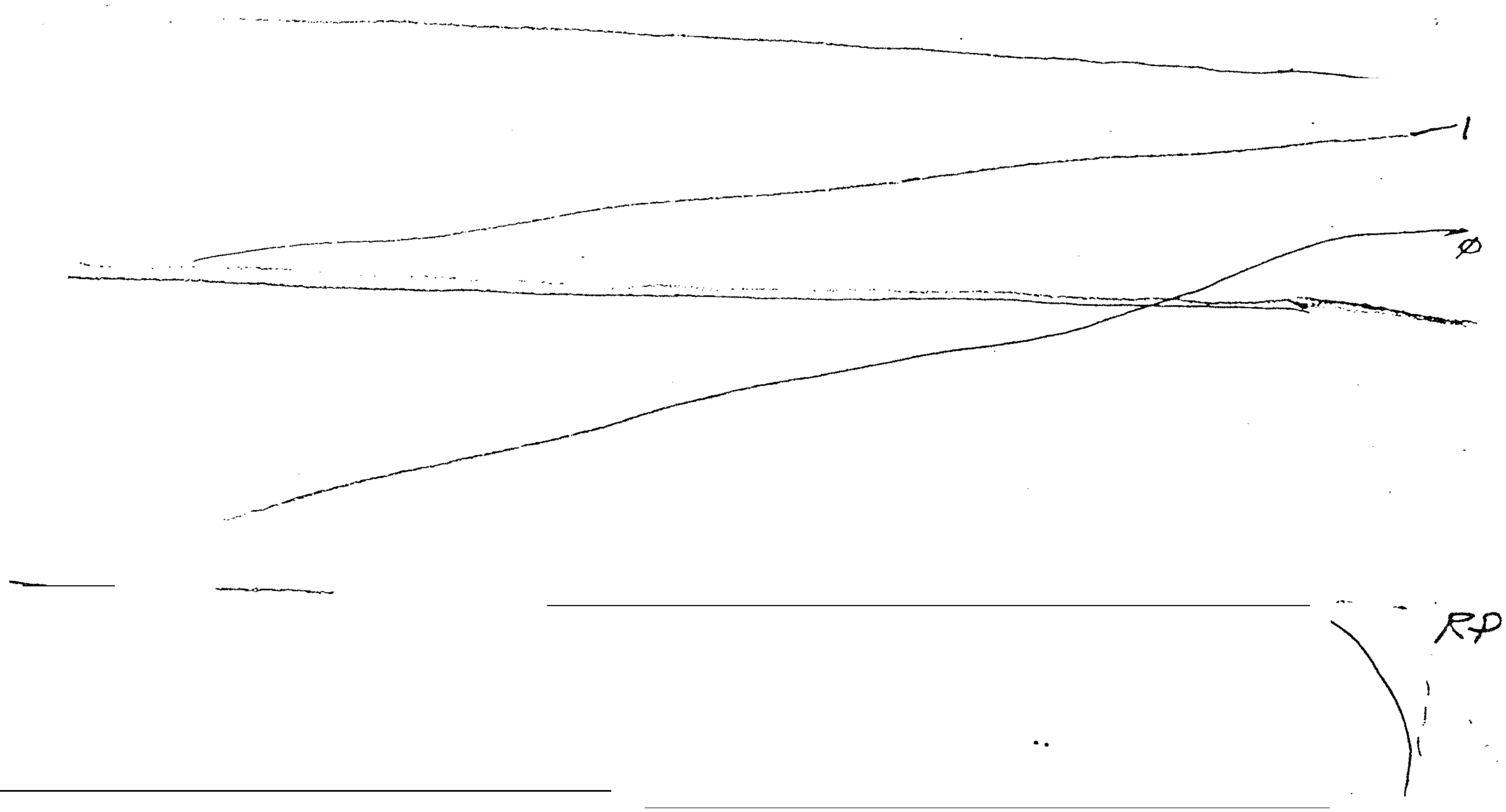
-SKIDS
RP 0 - N-16 FT.
RP 1 N-20
W-5 2 N-14
W-5 3 N-19
W-10 4 N-13
W-10 5 N-18
W-15 6 N-12
W-15 7 N-17
W-40 8 N-11
W-50 9 N-10
W-70 10 N 9/10
W-80 11 N-9

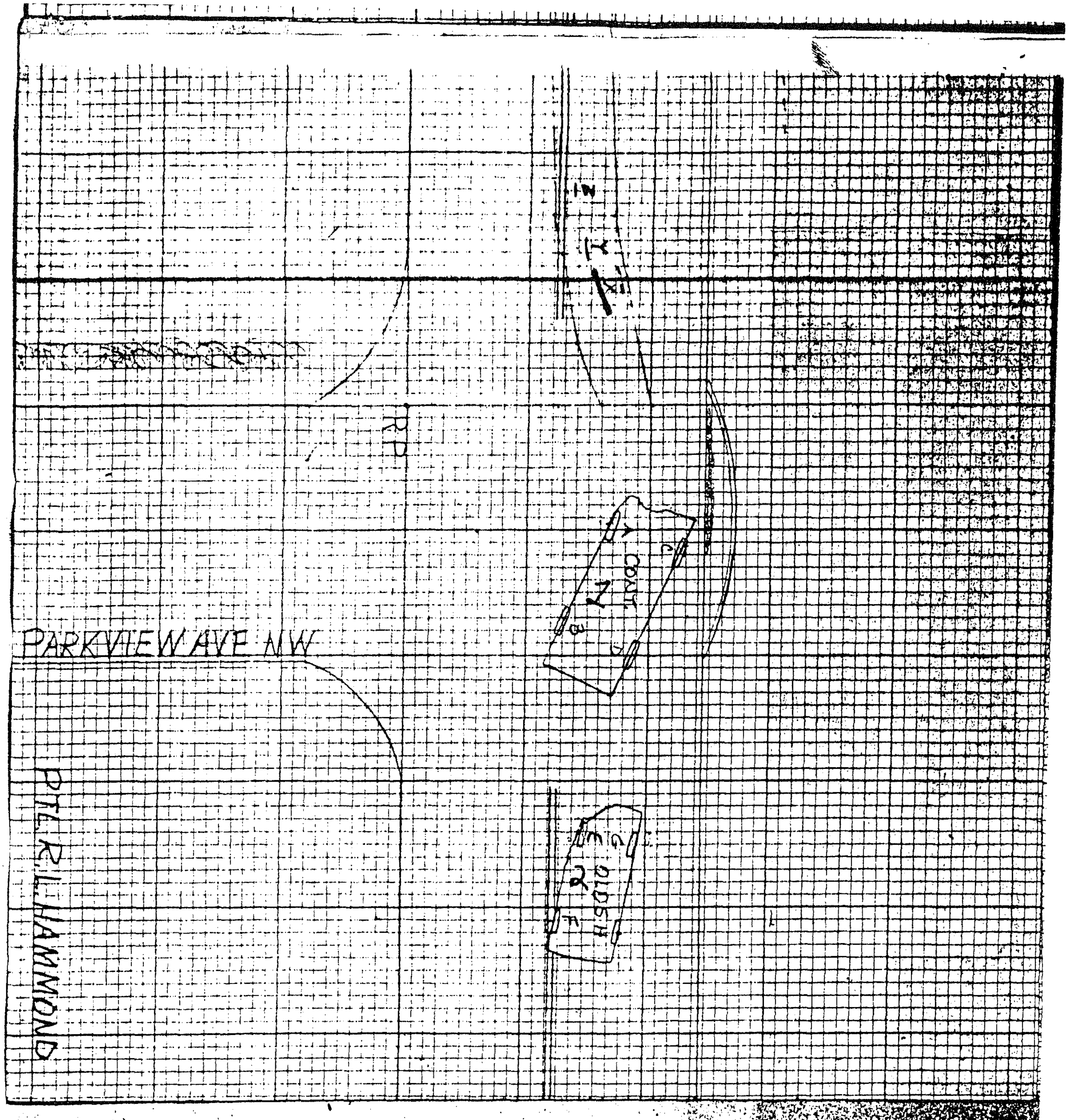
EVERY 20 FT

Point #
W-90 12 N-13-6
W-108 13 N-12/10

GOUGE
24 in X W-10 - N 18 1/4 in
18 in Y W-13 - N 14-6
12 in Z W-17 1/2 - N 13-6

R L Hammond

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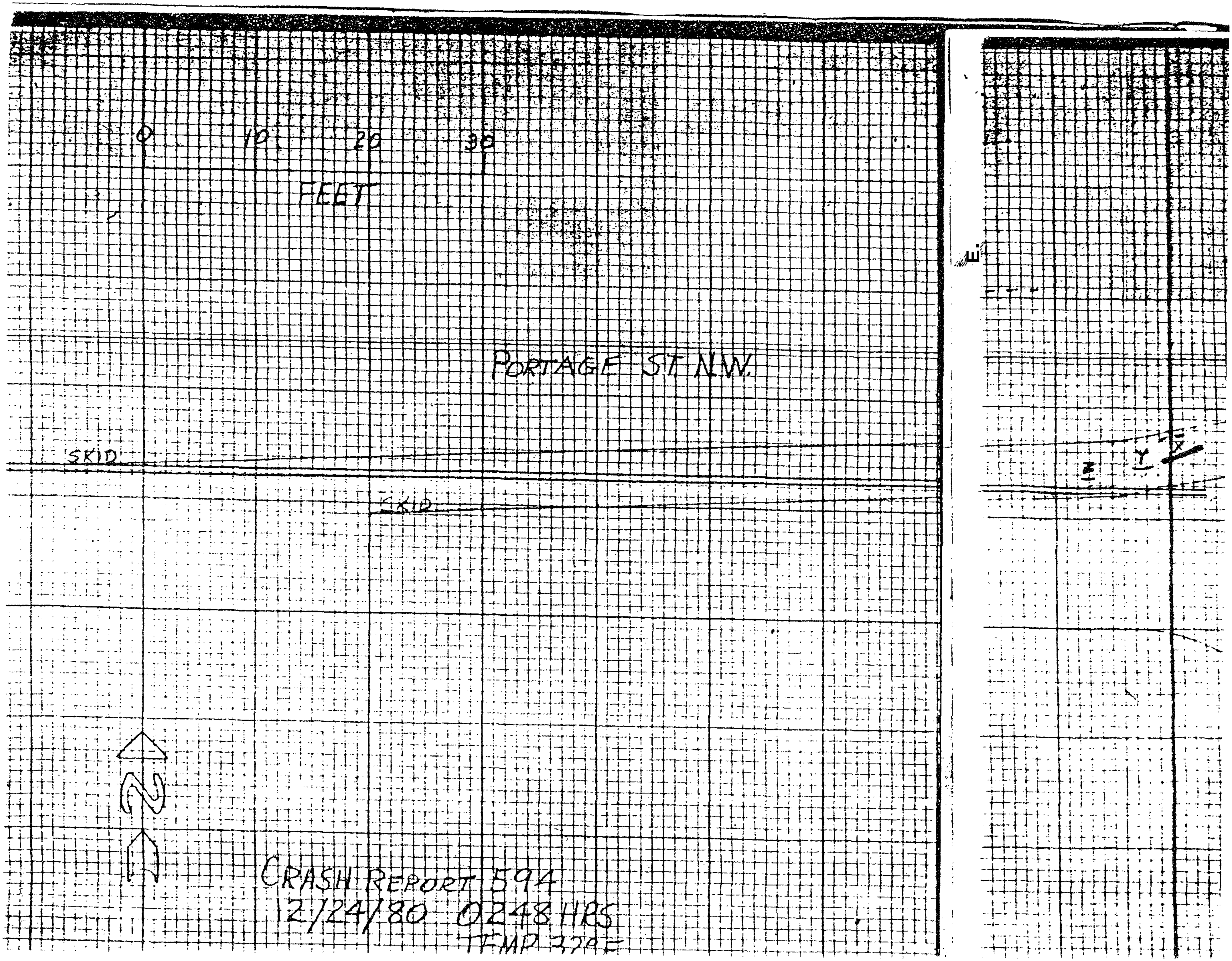
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INTERESTING CASE

This accident involves three vehicles: a 1973 semi-tractor-trailer, a 1974 Chevrolet Nova, and a 1966 Cadillac. I will identify them as vehicles numbers 1, 2, and 3, respectively. The Nova was making a rather wide left turn and it was hit by the semi-tractor-trailer on the passenger side as it crossed the oncoming curb lane. After impact the Nova spun about 180° clockwise as it slid about 32 ft into the Cadillac which was standing at the light waiting to enter the intersection. The Nova's passenger side struck vehicle #3's driver's side and both vehicles bounced and slid sideways to a stop.

The tractor-trailer laid down 20 ft of skidmarks before the impact point, 88 ft of skidmarks after the impact point, began to jackknife at impact, and jumped a six-inch curb with its right-side front wheel and came to a stop.

Figure 1 is the diagram from the police report. It shows the final resting place of the 3 vehicles and indicates that the tandem axles (power axle [illegible] emi left 108 ft of skidmarks. The central question [illegible] d the possible liability of the driver of the tr[illegible] peeding, then he was at least in part respons[illegible] As a result, my part in the reconstruction centered on his [illegible] ondary part of the reconstruction was locating the truck at [illegible] instant the Nova began its left turn. By noting the time from the start of the turn to impact for the Nova and working backwards from the impact, it is possible to place the tractor-trailer at this instant. Then one can determine whether or not it had an adequate distance in which to stop and possibly avoid the impact if it had been traveling at or below the speed limit (35 mph in this case).

Figure 2 is a copy of my scale drawing of the intersection showing vehicle #2 at the start of its turn, vehicles #1 and #2 at impact, and the final resting position of all three vehicles. Figure 3 shows the intersection and Gilchrist Road with several reference poles east of the intersection.

As it turned out, the entire question of whether or not the tractor-trailer was speeding rested on the skidmark statement in the police report. The Ohio State patrolman wrote that the 108 ft skidmark was due to the tandem (power) axles of the tractor-trailer. If this was the case,, then, as I will demonstrate, the tractor-trailer was speeding. If the patrolman was in error or unsure of his statement after questioning, however, one could imagine the 108 ft of skidmarks beginning with the rear wheels of the trailer and ending at the resting position of the tractor's power axle. In this instance, one would have to subtract approximately 35 ft from the total skidlength, This is the distance between the rear trailer axle and the power axle of the tractor. As a result, the total skid of each wheel would have been about 73 ft in length. For this situation, the calculations show that the tractor-trailer possibly was not exceeding the speed limit of 35 mph.

No other witness observed the skidmarks as carefully as the patrolman, and no picture taken at the scene showed the beginning of the skid. As a result, there was not any photographic evidence to show overlap or the lack of it at the start of the skidmarks or indicate that the skid was either 108 ft or 73 ft.

There was a second question regarding the speed computation. Initially, the trucking company said there were brakes on all axles (including the steering axle) of the tractor-trailer. For this situation, the entire weight of the tractor-trailer ($\sim$ 24,000 lbs) would be effective in slowing the vehicle in a skid. Later they changed their mind and said that the steering axle was without brakes. In this instance, the 7,000 to 10,000 lbs carried by the front axle would not be effective in slowing the truck in a skid. As a result, without brakes on the front axle, the speed at the start of a skid of a given length would have been less than the computed speed if this axle did have brakes.

To be noted here is the fact that all of the action at impact and afterwards by the Nova and subsequently the Cadillac plays a very small role in the speed computation of the tractor-trailer. Because of the weight differences between the Nova and the tractor-trailer, the impact, the 32-ft skid of the Nova, the collision with the Cadillac, and the subsequent sliding of both the Nova and the Cadillac to a stop only account for about 10% of the initial speed of the tractor-trailer.

The actual breakdown of the accident for analysis purposes is listed below. As always, we will begin with the final resting position of the vehicles.

1. Determination of vehicle #3's speed sideways after it was hit on the side by the Nova. Conservatively, the Cadillac slid 6 inches sideways to a stop. (Work-energy relation)
2. Determination of the Nova's speed just after impact with the Cadillac. It slid sideways about 4 ft after impact. (Work-energy relation)

3. Determination of the Nova's speed just prior to its impact with the Cadillac. Here, the Cadillac is taken to be at rest prior to impact. (Conservation of momentum)

4. Determination of the Nova's speed at the beginning of its 32-ft slide and spin between impacts. (Work-energy relation)

5. Determination of the tractor-trailer's speed just after its impact with the Nova; that is, at the start of its 88-ft post-impact skid. (Work-energy relation)

6. Determination of the speed of the tractor-trailer just prior to impact with the Nova. (Conservation of momentum)

7. Determination of the tractor-trailer's speed at the beginning of its 20-ft pre-impact skid.

8. Determination of the distance traveled by the Nova from a stopped position at the light to the impact point.

9. Determination of the time required for the Nova to make the turn. [Here testimony indicated that the turn was rather slow (∿ 5 mph).]

10. Determination of the tractor-trailer back from the impact point at the point in time when the Nova begins its left turn (using the time required for the Nova to regotiate the turn and the tractor-trailer's pre-skid speed).

Analysis

1. Speed of Cadillac at the start of its 6" post-impact sideways slide

Equation: $v_1^2 = 2 \mu g d_1$ $\qquad g = 32.2\ \text{ft/sec}^2$

$v_1^2 = 2(0.6 \leftrightarrow 0.8)(32.2)(.5)$ $\qquad \mu = 0.6 \leftrightarrow 0.8$

$v_1 = 4.4 \leftrightarrow 5.1\ \text{ft/sec}$ $\qquad d_1 = 0.5\ \text{ft}$

Result: $v_1 = 3.0 \leftrightarrow 3.5\ \text{mph}$

2. Speed of Nova at the start of its 4 ft sideways slide after impact with the Cadillac.

Equation: $v_2^2 = 2 \mu g d_2$ $\qquad g = 32.2\ \text{ft/sec}^2$

$v_2^2 = 2(0.6 \leftrightarrow 0.8)(32.2)(4)$ $\qquad \mu = 0.6 \leftrightarrow 0.8$

$v_2 = 12.4 \leftrightarrow 14.4\ \text{ft/sec}$ $\qquad d_2 = 4\ \text{ft}$

Result: $v_2 = 8.4 \leftrightarrow 9.8\ \text{mph}$

3. Speed of Nova before impact with the Cadillac.

Equation: $m_N v_3 = m_N v_2 + m_C v_1$

m_N = mass of Nova = $\dfrac{3600\ \text{lbs}}{32\ \text{ft/sec}^2}$

m_C = mass of Cadillac = $4800\ \text{lbs}/32\ \text{ft/sec}^2$

v_3 = pre-impact speed of Nova

$v_1 = 3.0 \leftrightarrow 3.5\ \text{mph}$

$v_2 = 8.4 \leftrightarrow 9.8\ \text{mph}$

$V_3 = (8.4 \leftrightarrow 9.8) + \frac{4800}{3600}(3.0 \leftrightarrow 3.5)$

$V_3 = 12.4 \leftrightarrow 14.5$ mph

↳ speed of Nova at the end of its 32 ft skid and spin just prior to hitting the Cadillac.

4. Speed of the Nova just after its impact with the tractor trailer and, therefore, at the beginning of its 32 ft skid and spin.

Equation: $V_4^2 = 2 \mu g d_3 + V_3^2$

V_4 = Nova's speed at the start of 32 ft skid

$\mu = 0.6 \leftrightarrow 0.8$

$d_3 = 32$ ft

$V_3 = 12.4 \leftrightarrow 14.5$ mph $(18.2 \leftrightarrow 21.3$ ft/sec$)$

$V_4^2 = 2(0.6 \leftrightarrow 0.8)(32.2)(32) + (18.2 \leftrightarrow 21.3)^2$

$V_4 = 39.5 \leftrightarrow 45.9$ ft/sec

Result: $V_4 = 27. \leftrightarrow 31.3$ mph

4a. After impact the Nova's direction of motion is 22° North of the western direction of Gilchrist Rd. We can consider the Nova as traveling parallel and perpendicular to Gilchrist Rd simultaneously. Hence:

$$V_{Nova \parallel Gilchrist} = V_4 \cos 22° = 25.0 \leftrightarrow 29.0 \text{ mph}$$
$$V_{Nova \perp Gilchrist} = V_4 \sin 22° = 10.1 \leftrightarrow 11.7 \text{ mph}$$

If the Nova was traveling at 5 mph in a direction perpendicular to the east-west direction of Gilchrist just prior to its impact with the tractor trailer --- then 5.1 ⟷ 6.7 mph of its post impact speed perpendicular to Gilchrist is due to the truck along with all of its speed parallel to Gilchrist.

As a result, the speed of the Nova due to the truck is:

$$V_5 = 25.5 \leftrightarrow 29.8 \text{ mph}$$

5. Speed of the tractor trailer just after its impact with the Nova.

Equation: $V_6^2 = 2 \mu g d_4 + V_7^2$

V_6 = post-impact speed of vehicle #1
μ = 0.35 ↔ 0.70
g = 32.2 ft/sec²
d_4 = 88 ft
assumption → V_7 = 10 mph (14.67 ft/sec) -- speed at which vehicle #1 hits the curb at the end of its 88 ft skid.

$V_6^2 = 2(0.55 \longleftrightarrow 0.70)(32.2)(88) + (14.67)^2$
$V_6 = 57.6 \longleftrightarrow 69.5$ ft/sec
Result $V_6 = 39.3 \longleftrightarrow 47.4$ mph

6. Speed of the tractor trailer just prior to its impact with the Nova.

Equation: $m_T V_8 = m_T V_6 + m_N V_5$

m_T = mass of #1 = $\frac{24370 \text{ lbs}}{32 \text{ ft/sec}^2}$

m_N = mass of Nova = $\frac{3600 \text{ lbs}}{32 \text{ ft/sec}^2}$

V_8 = pre-impact speed of #1

$V_6 = 39.3 \leftrightarrow 47.4$ mph
$V_5 = 25.5 \leftrightarrow 29.8$ mph

$$V_8 = (39.3 \leftrightarrow 47.4) + \frac{3600}{24370}(25.5 \leftrightarrow 29.8)$$

Result: $V_8 = 43.1 \leftrightarrow 51.8$ mph ($63.2 \leftrightarrow 76.0$ ft/sec)

7. Speed of #1 at the start of its 20 ft pre-impact skid.

Equation: $V_9^2 = 2 \mu g d_5 + V_8^2$

$\mu = 0.55 \leftrightarrow 0.70$
$g = 32.2$ ft/sec^2
$d_5 = 20$ ft
$V_8 = 63.2 \leftrightarrow 76.0$ ft/sec

$$V_9^2 = 2(0.55 \leftrightarrow 0.70)(32.2)(20) + (63.2 \leftrightarrow 76.0)^2$$

$V_9 = 68.6 \leftrightarrow 81.7$ ft/sec

Result: $V_9 = 46.8 \leftrightarrow 55.7$ mph

(Note: If one assumes that #1 hit the curb after its 88 ft post-impact skid at 0 mph the resulting range for the speed of the tractor trailer at the start of its pre-impact skid is reduced by less than one mph.

Further, if one assumes that the Cadillac was not moved by the impact of the Nova, the effect is to reduce the pre-skid speed of #1 by less than one mph.

8. The distance traveled by the Nova from the start of its turn to impact is 49 ft. (From testimony and scale diagram.)

9. Time to go from 0 → 5 mph at a slow acceleration (3.0 ft/sec²) plus the time to travel the remainder of the 49 ft at a constant speed of 5 mph.

Equation: $V' = a t_1$

t_1 = time to get from 0 – 5 mph

V' = 5 mph (7.33 ft/sec)

a = 3.0 ft/sec²

Result. $t_1 = \frac{7.33}{3.0} = 2.44$ sec.

The distance traveled is $d_6 = \frac{1}{2} a t_1^2$

$$d_6 = \frac{1}{2}(3.0)(2.44)^2$$

$d_6 = 8.94 ft$

Remaining distance $d_7 = 49 - 8.94$

$d_7 = 40.06 ft.$

Equation: $t_2 = \frac{d_7}{V'} = \frac{40.06 ft}{7.33 ft/sec}$

$t_2 = 5.46 sec.$

Total time for turn $= t_1 + t_2$

$t_{total} = 7.9 sec.$

10. The position of #1 when the Nova began its turn.

Working backwards: The time required for #1 to skid 20 ft prior to impact is 0.25 ↔ 0.30 sec. Thus, the position of the truck between 7.6 ↔ 7.65 seconds prior to its pre-impact skid is given by:

Equation: $d_8 = V_9 t_3$

d_8 = #1's position when the Nova began its turn.

$V_9 = 46.8 \leftrightarrow 55.7$ mph $(68.6 \leftrightarrow 81.7$ ft/sec$)$

$t_3 = 7.6 \leftrightarrow 7.65$ sec

$d_8 = (68.6 \leftrightarrow 81.7)(7.6 \leftrightarrow 7.65)$

Result: $d_8 = 522 \leftrightarrow 625$ ft

Conclusions:

1. The pre-skid speed of the tractor-trailer was in the range from 46 to 56 mph.
2. The time for the Nova to negotiate the left turn (49 ft) to impact was 7.9 seconds.
3. The position of the tractor-trailer 7.9 seconds prior to impact was between 522 ft and 625 ft east of the impact point.

Comments:

1. Witnesses placed the tractor-trailer at the 3rd pole east of the intersection when the Nova began the turn, The 3rd pole is about 580 ft east of the impact point. Clearly, this is consistent with the result given in #3 above,
2. The stopping distance can easily be computed for the tractor-trailer, The stopping dl'stance is the total distance traveled during the driver reaction time and 0.4 sec brake-lag time plus the distance required for a locked wheel skid to a stop,

Let's assume a rather long reaction time of 1.5 seconds. Thus the total time traveled before braking begins is 1.5 + 0.4 = I.9 seconds.

Consl'der 3 speeds ($d \equiv$ distance traveled in 1.9 seconds):

1. Speed limit 35 mph = 51.3 ft/sec.

   $d = vt = (51.3)(1.9) = 97.5$ ft
2. Minimum tractor-trailer speed of 46 mph = 67.5 ft/sec.

   $d = vt = (67.5)(1.9) = 128.3$ ft
3. Maximum tractor-trailer speed of 56 mph = 82.1 ft/sec.

   $d = vt = (82.1)(1.9) = 156.0$ ft

The distance required for a locked wheel skid from each of the above speeds may be computer from $v^2 = 2\mu g d_{l.w}$, where

v = speed

$\mu = 0.55 \leftrightarrow 0.70$

$g = 32.2$ ft/sec^2

$d_{l.w.}$ = distance of locked wheel skid

Speed:

1. 35 mph = 51.3 ft/sec.

$$d_{l.w.} = \frac{(51.3)^2}{2(32.2)(0.55 \leftrightarrow 0.70)}$$

$= 58.4 \leftrightarrow 74.3$ ft

2. 46 mph = 67.5 ft/sec

$$d_{l.w.} = \frac{(67.5)^2}{2(32.2)(0.55 \leftrightarrow 0.70)}$$

$= 101.1 \leftrightarrow 128.6$ ft

3. 56 mph = 82.1 ft/sec

$$d_{l.w.} = \frac{(82.1)^2}{2(32.2)(0.55 \leftrightarrow 0.70)}$$

$= 149.5 \leftrightarrow 190.3$ ft

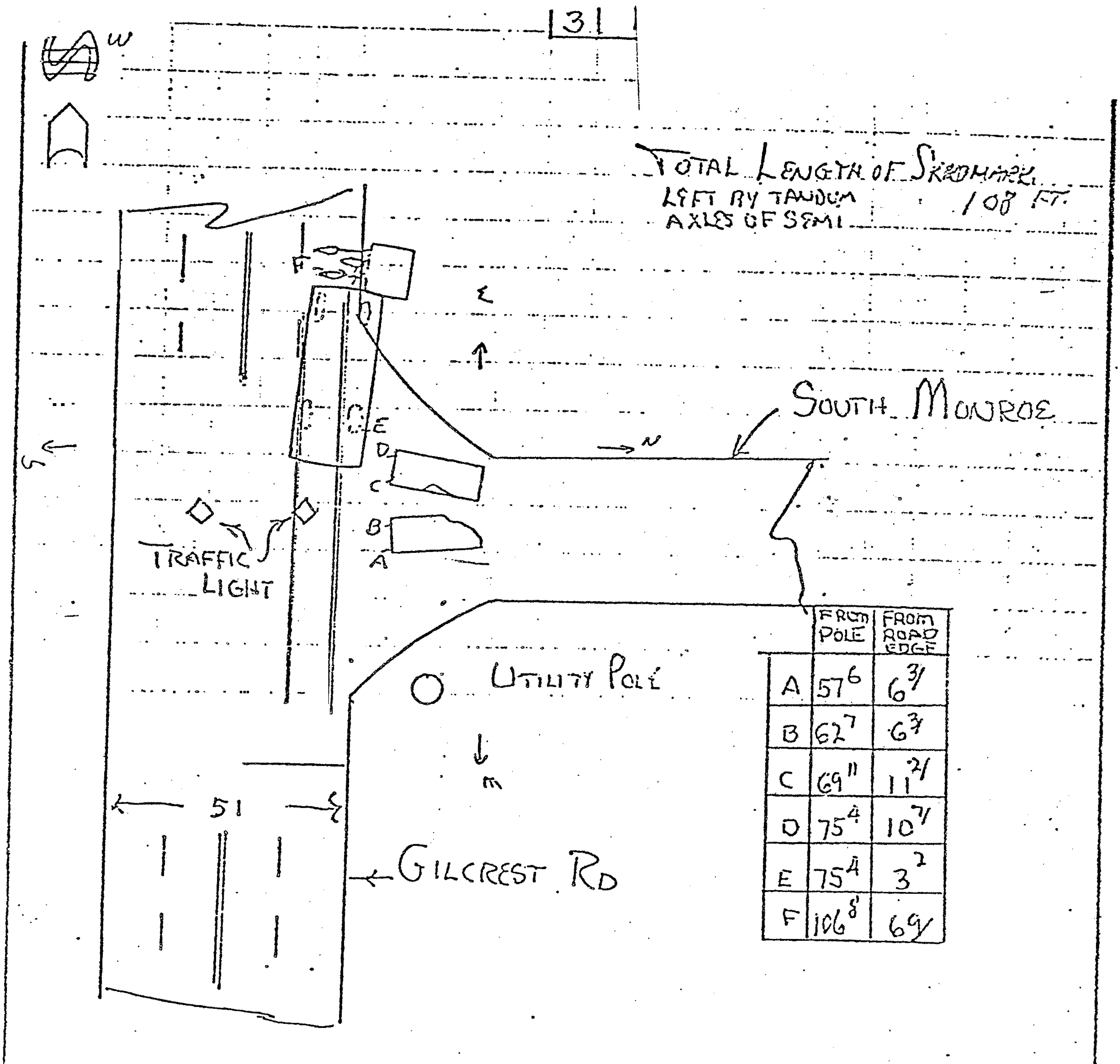
The total stopping distances are therefore:

Total Distance $= d + d_{l.w}$

Speed	Range of Total Stopping Distances
35 mph	155 ↔ 172 ft
46 mph	230 ↔ 257 ft
56 mph	306 ↔ 346 ft

The only conclusion is that the tractor-trailer could have come to a complete stop at least 175 ft east of the impact point even if it was traveling at 56 mph.

Figure 1

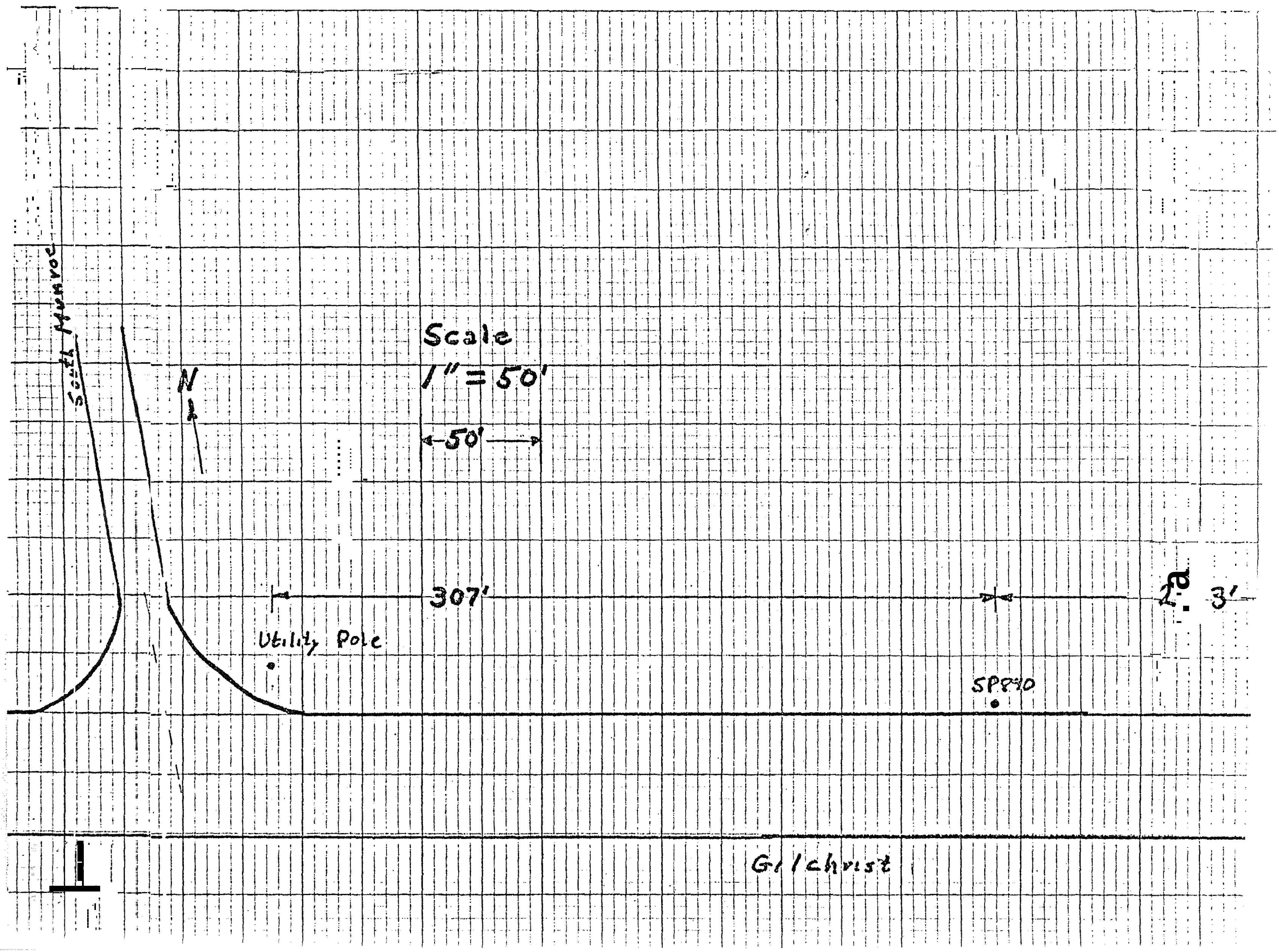


	FROM POLE	FROM ROAD EDGE
A	57^{6}	$6^{3/}$
B	62^{7}	$6^{3/}$
C	69^{11}	$11^{2/}$
D	75^{4}	$10^{7/}$
E	75^{4}	3^{2}
F	106^{8}	69/

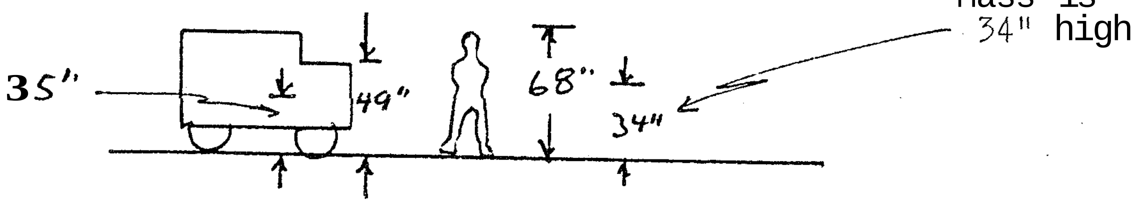
OFFICER'S SIGNATURE: Tpr D K Pike

ID NUMBER: 1496-77-3

OH-2 (REV. 5/73)


South Munroe
N
Scale
1" = 50'
50'
307'
3'
Utility Pole
SP840
Gilchrist

Victim 5'8" tall = 68" tall



Victim thrown 50'7"

Victim falls 34" = 2.83'

$d = v_o t + \frac{1}{2}at^2$

$2.83' = \frac{1}{2}(32)t2$

$t^2 = 0.1759$

$t = 0.419$ sec

Distance thrown is 50'7"

Assume no air friction to slow the horizontal travel of the victim

~~$d = v_{vic}t + \frac{1}{2}at^2$~~

~~$d = 50.6' = v_{vic}(.419)$~~ $50.6' = v_{vic}(.419)$

$v_{vic} = 120.7$ ft/sec

Speed of victim @ takeoff about twice around of vehicle @ impact

Just also — height of flight — greater the arc — less velocity of speed of vehicle

If perfectly elastic collision, then no energy lost to deformation.

Conservation of Energy (1) Before After

$$\frac{1}{2}MV_o^2 = \frac{1}{2}MV^2 + \frac{1}{2}mv_{vic}^2$$

$$+ (W)$$

(W) energy lost to deformation

Conservation of Momentum (2) $MV_o = MV + mv_{vic}$

Algebraically eliminate V (Speed of truck after impact) from (1) & (2).

The result is:

(Speed of Truck Before the Collision) $$V_o = \frac{v_{vic}}{2}\left(1 + \frac{m}{M}\right)$$

If $W > 0$, then V_o increases --

So this V_o is a minimum speed

Weight of victim = mg = 150 lbs

Weight of truck = Mg = 4770 lbs

$$V_o = \frac{120.7}{2}\left(1 + \frac{150}{4770}\right)$$

$$V_o = \frac{120.7}{2}(1 + .0314)$$

$$V_o = 62 \text{ ft/sec}$$

$$V_o = 42 \text{ mi/hr}$$

Minimum because:

1. Allowed no air friction or dragging along the ground to slow down the victim

2. We allowed no loss of energy due to deformation of truck or victim in the collision

Consider two cars entering an intersection and both stop with the driver even with the stop sign. See figure.

#1 $0 \rightarrow 5$ mph (7.3 ft/sec)

#2 $0 \rightarrow 3$ mph (4.4 ft/sec)

#1 $v^2 - v_o^2 = 2ad$

$(7.3)^2 - (0)^2 = 2a(32)$

$a_1 = 0.83$ ft/sec^2

#2 $v^2 - v_o^2 = 2ad$

$(4.4)^2 - (0)^2 = 2a(12)$

$a_2 = 0.81$ ft/sec^2

#1 $\frac{v - v_o}{t} = a_1$ $\qquad v - v_o = at$

$7.3 - 0 = (0.83)t$

$t_1 = 8.8$ sec

Note: If #1 did not stop, then at 5 mi/hr (7.3 ft/sec)

$t_1 = \frac{32}{7.3} = 4.4$ sec.

#2 $v - v_o = a_2 t$

$4.4 - 0 = 0.81t$

$t_2 = \frac{4.4}{.81} = 5.4$ sec.

It took car #1

$8.8 - 5.4 = 3.4$ sec

longer to get from the stopped position to the point of impact than car #2.

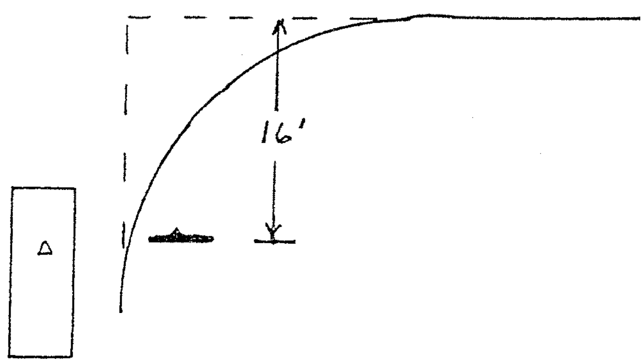
So car #1 entered the intersection 3.4 sec before car #2.

Implies car #2 at fault.

Assumptions

1. Both cars went from 0 to speed of impact with constant acceleration

2. Both cars came to a full stop with driver abreast at the stop sign - 16' from the edge of the cross-street



Car #1 gushed sideways out of its original lane

Front wheels moved 14' west

Rear wheels moved 9' west

Average distance pushed $\frac{14^{1} + 9^{1}}{2} = 11.51$

Cry travelled asphalt

$\mu = .55 - .70$

$\mu = .55 \qquad v^2 = 2\mu g d$

$v^2 = 2(.55)(32)(11.5)$

$v = 20.1$ ft/sec

$v = 13.7$ mi/hr

$\mu = .70 \qquad v^2 = 2(.70)(32)(11.5)$

$v = 22.7$ ft/sec

$v = 15.5$ mi/hr

Range of speeds for #1 in westerly direction at the instant after impact

13.7 - 15.5 mi/hr

Use Conservation of Momentum

during the Collision (along east-west direction)

Before After

$$m_1 v_1 + m_2 v_2 = m_1 v_1^1 + m_2 v_2^1$$

($v_1 \rightarrow 0$)

Best case for #2 is if v_2^1 (speed. of #2 after impact) <u>is 0</u>

Let $v_2^1 = 0$

Say $W_2 = 2500$ lbs

$W_1 = 3500$ lbs

for $v_2^1 = 0$ and $v_1 = 0$ Recall $W = mg$ so $m = \frac{W}{g}$

$$m_2 v_2 = m_1 v_1^1$$

$$\frac{W_2}{g} v_2 = \frac{W_1}{g} v_1^1$$

$$\frac{2500}{32} v_2 = \frac{3500}{32} v_1^1$$

$$v_2 = \frac{35}{25} v_1^1 = \frac{7}{5} v_1^1$$

$$v_1^1 = 13.7 - 15.5 \text{ mi/hr}$$

$$v_2 = \frac{7}{5}(13.7)$$

$$= 19.2 \text{ mi/hr}$$

$$v_2 = \frac{7}{5}(15.5)$$

$$= 21.7 \text{ mi/hr}$$

<u>Minimum</u> Range of speeds for #2 just before impact is

19 - 22 mi/hr

#2	18'	v = 3 mi/hr	Both cars stop with the front bumpers even with the stop sign.
#1	38'	v = 5 mi/hr	

3 mi/hr = 4.4 ft/sec
5 mi/hr = 7.3 ft/sec

#1 $(7.3)^2 = 2a(38)$

$51 = 76a$

$a_1 = \frac{51}{76} = .67 \text{ ft/sec}^2$

#2 $(4.4)^2 = 2a(18)$

$18 = 36a$

$a_2 = \frac{18}{36} = .5 \text{ ft/sec}^2$

$v - v_0 = at$

#1 $7.3 = (.67)t$

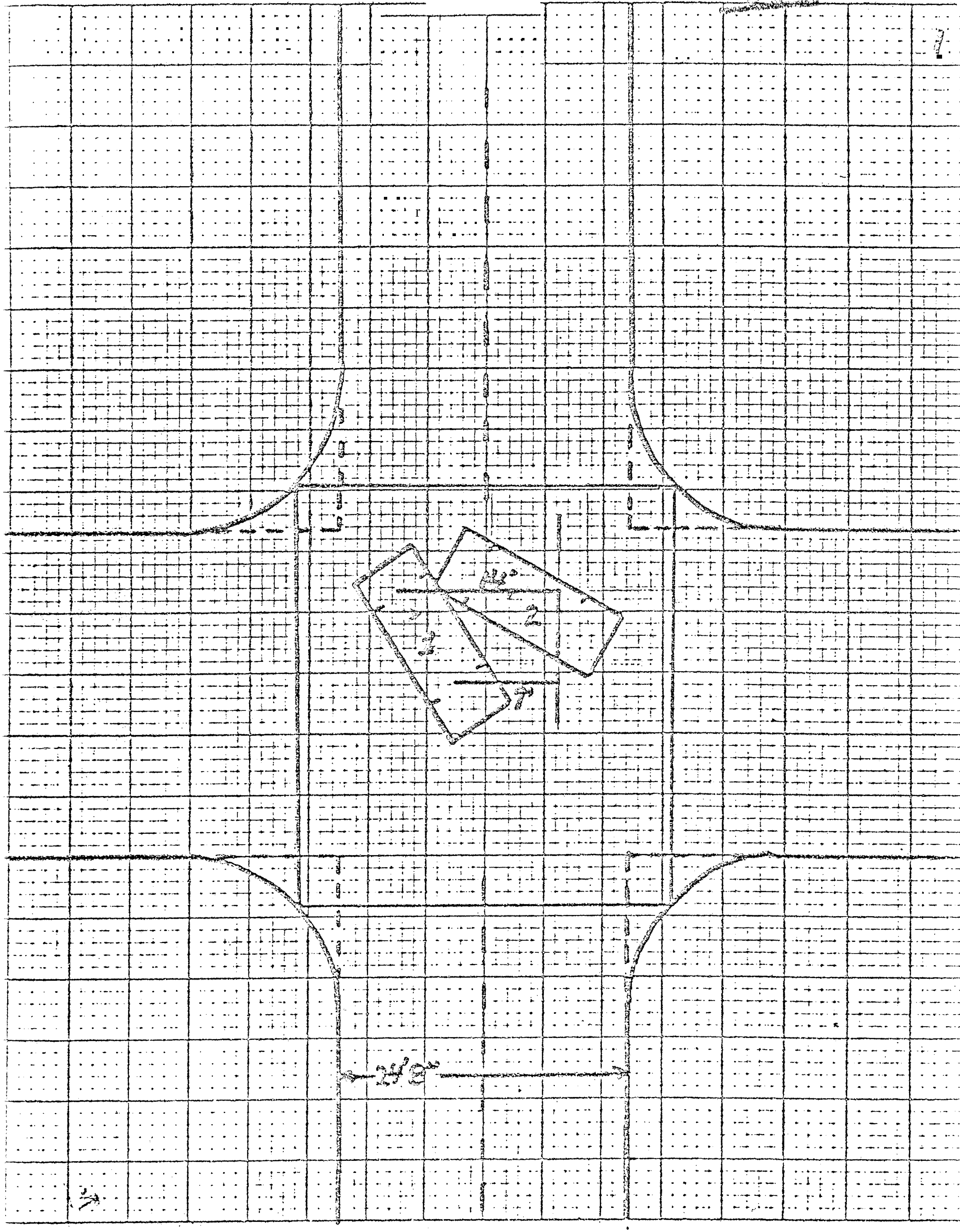
$t_1 = \frac{7.3}{.67} = 10.9$ sec

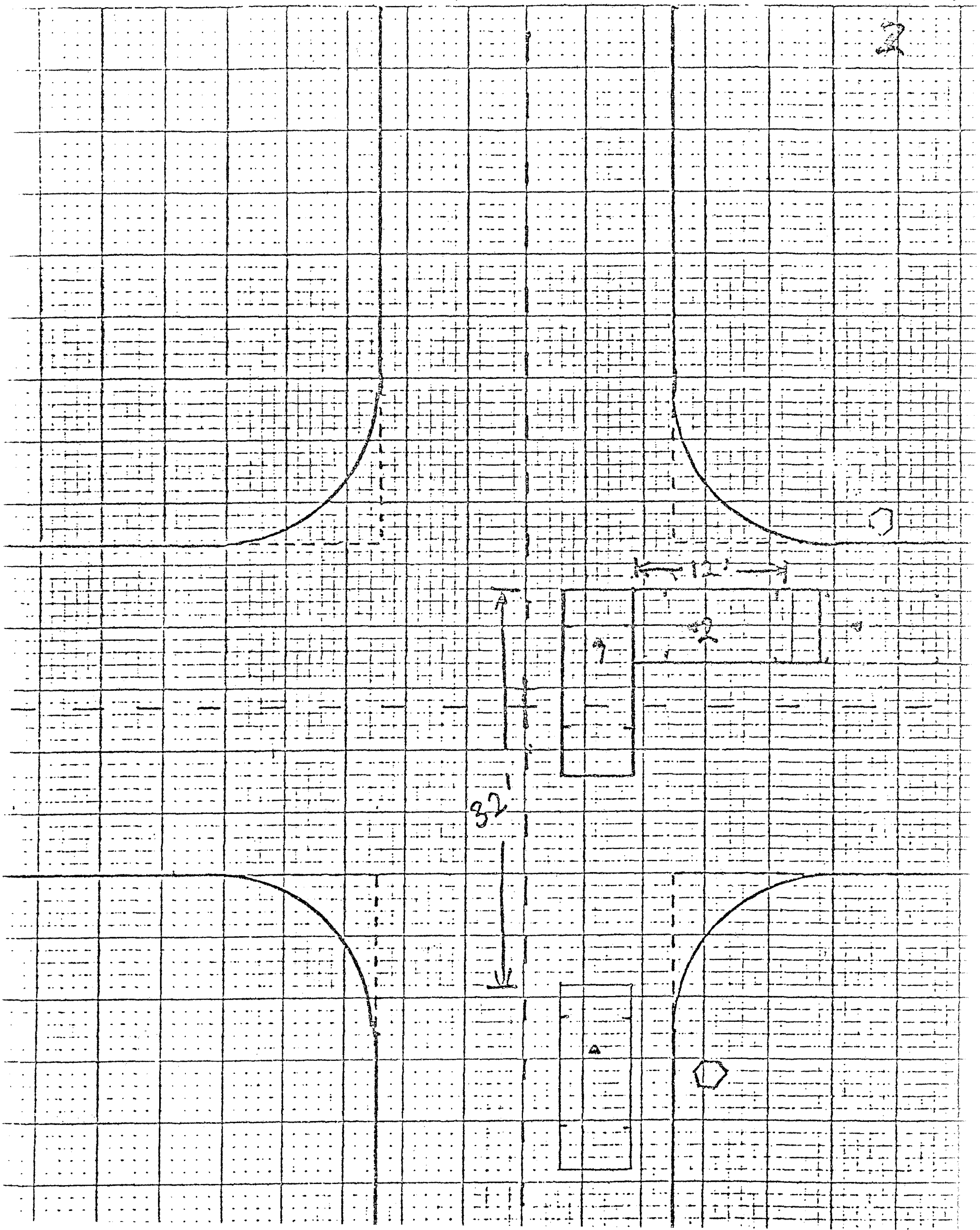
#2 $4.4 = .5t$

$t_2 = \frac{4.4}{.5} = 8.8$ sec

VI ULRICH

7




12'
32'

Kinematic Equations -- These equations are used when a vehicle, pedestrian, or a motorcycle rider becomes airborne.

1) $V_{average} = \frac{d}{t} = \frac{V_{final} + V_{initial}}{2}$

d = distance
t = time
V = velocity

$V_f = V_{final}$
$V_i = V_{initial}$

a = acceleration

2) $a = \frac{V_f - V_i}{t}$

Solve (1) and (2) for $\frac{1}{t}$ and equate

$$\frac{1}{t} = \frac{V_f + V_i}{2d} = \frac{a}{V_f - V_i}$$

$$(V_f + V_i)(V_f - V_i) = 2ad$$

$$V_f^2 + V_iV_f - V_iV_f - V_i^2 = 2ad$$

3) $V_f^2 - V_i^2 = 2ad$

Solve (1) and (2) for V_f and equate

$$V_f = V_i + at = \frac{2d}{t} - V_i$$

Solve for d

4) $d = V_it + \frac{1}{2}at^2$

Where does $V = 5.46\sqrt{\mu d}$ come from?

Consider

$\frac{1}{2}mv^2 = \mu mgd$

Cancel m's

$\frac{1}{2}v^2 = \mu gd$

Multiply by 2

$v^2 = 2\mu gd$

Take Square Root

$v = \sqrt{2\mu gd}$

Let g = 32.2 ft/sec^2

μ = drag factcr

d = distance in feet

v = speed in ft/sec $\therefore V = \sqrt{2(32.2)\mu d} = \sqrt{64.4}\sqrt{\mu d}$

Convert to mi/hr by dividing by 1.47

$v = \frac{\sqrt{64.4}}{1.47}\sqrt{\mu d} = 5.46\sqrt{\mu d}$

so speed in mi/hr is $v = 5.46\sqrt{\mu d}$

Co efficient of Friction remains the same whether the tire has tread or no tread.

Drag factor for legal brakes in Ohio

$d = 30\,ft$

$V_{start} = 20\,mph = 29.3\,ft/sec$

$\frac{1}{2} m V^2 = \mu m g d$

drag factor dissipating energy in brakes

$$\frac{(29.3)^2}{2(32.2)\,30\,ft} = \mu$$

$\mu = 0.445$ = drag factor for legal brakes

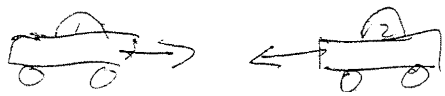
Average vehicle weight distribution in Auto is 53-60% on the front axles

Conservation of Momentum

Change in Momentum

pg. 13 last weeks handout

$$F_1 = -F_2$$



$$F = ma$$

$$F_1 = m_1 a_1 = \frac{V_1 f - V_1}{t}$$

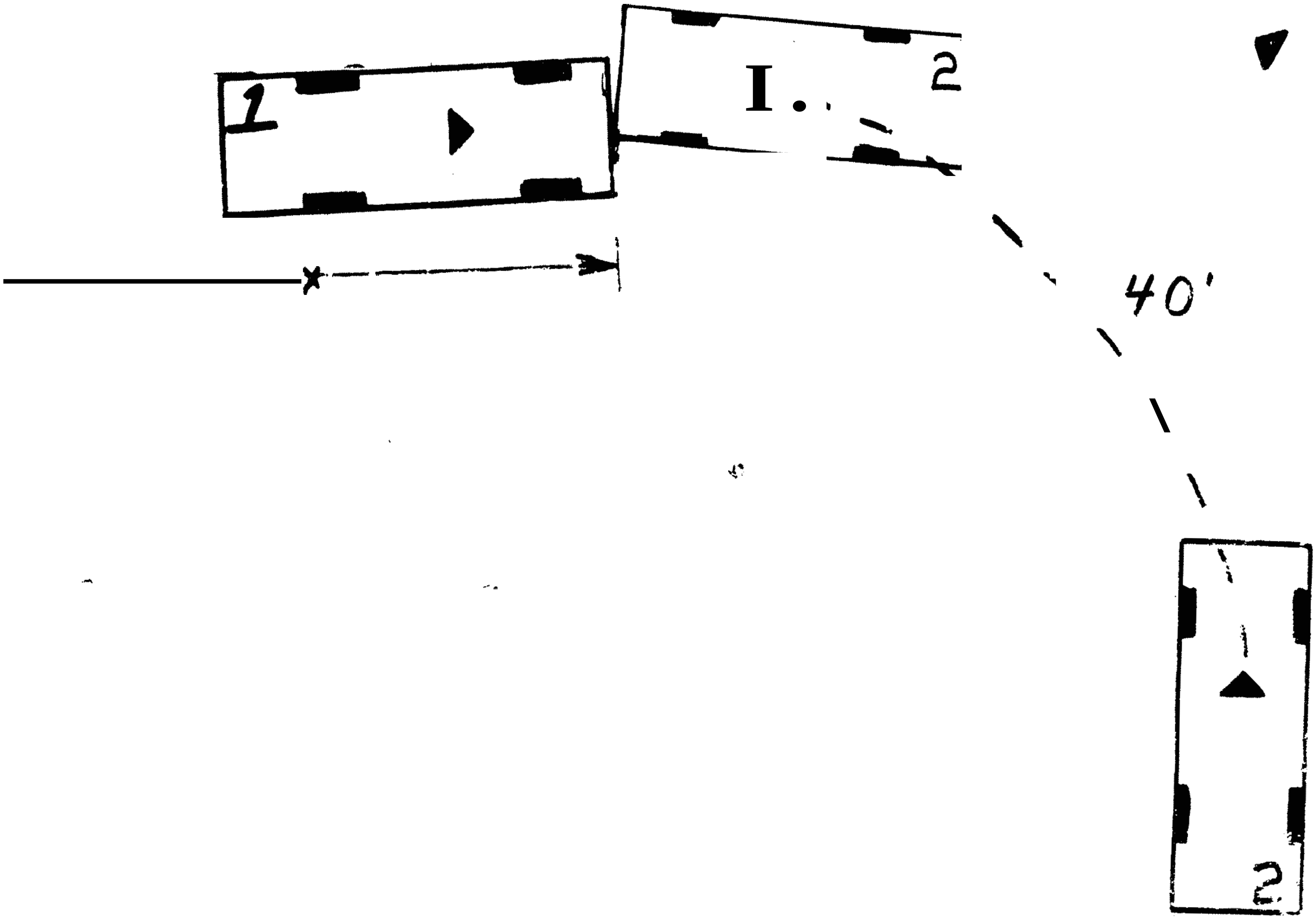
$$2 = m_2 a_2 = m_1 \frac{V_2 f - V_2}{t}$$

$$m_1 \left(\frac{V_1 f - V_1 i}{t}\right) = m_2 \left(\frac{V_2 f - V_2 i}{t}\right)$$

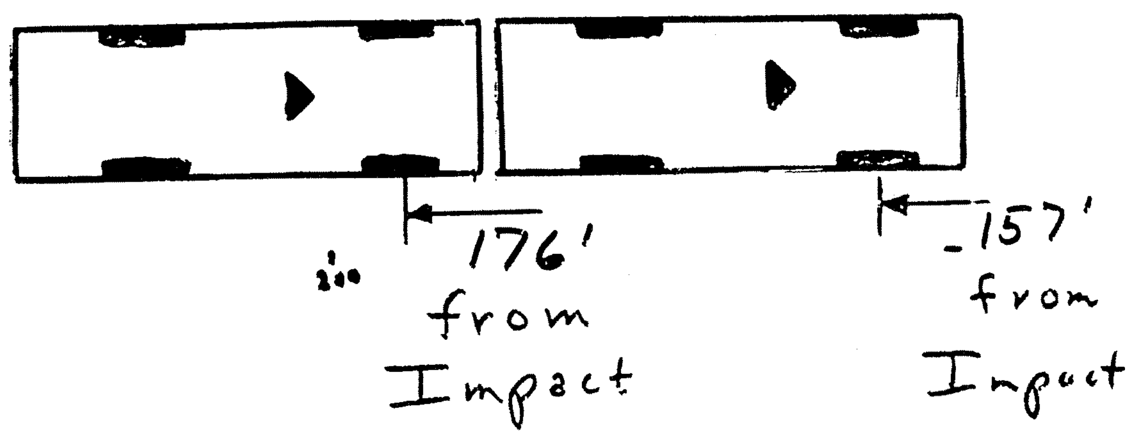
$$\underbrace{m_1 V_1 f - m_1 V_1 i}_{\text{change in momentum of \#1}} = -\underbrace{[m_2 V_2 f - m_2 V_2 i]}_{\text{change in momentum of \#2}}$$


2
87'

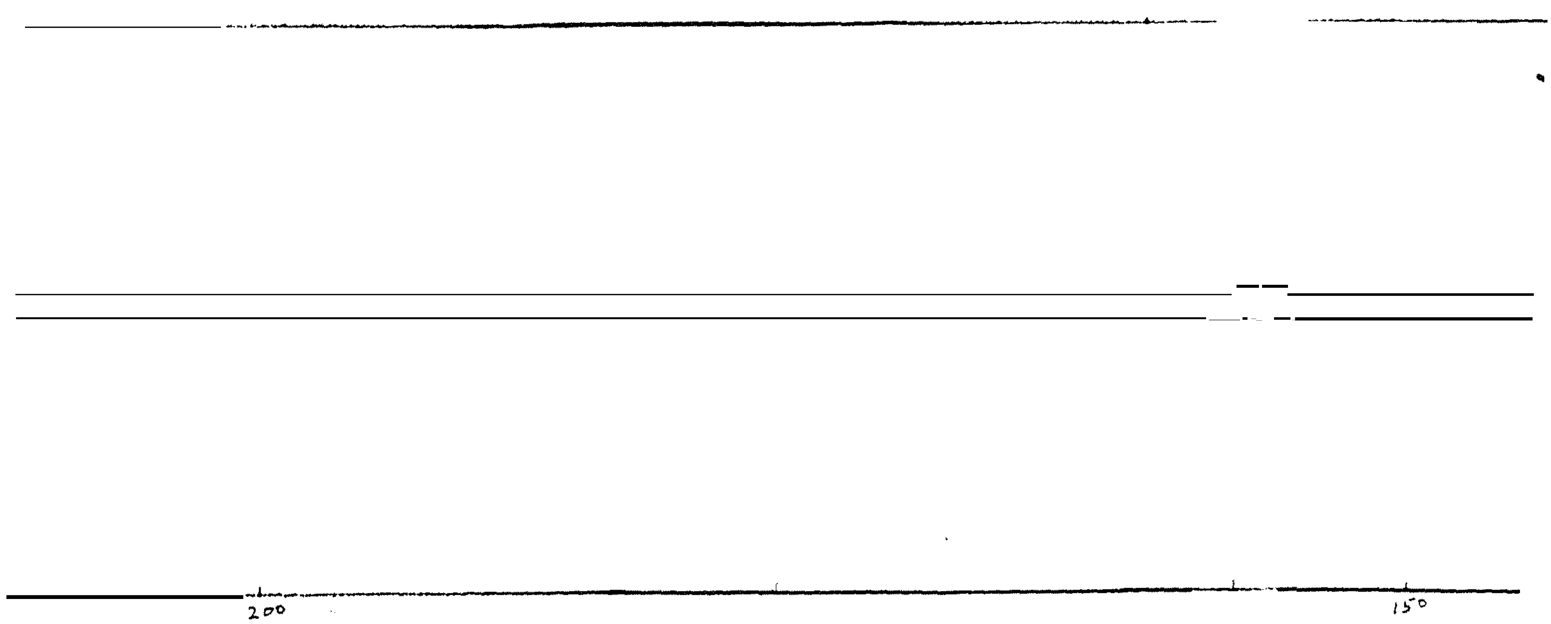

1
87'

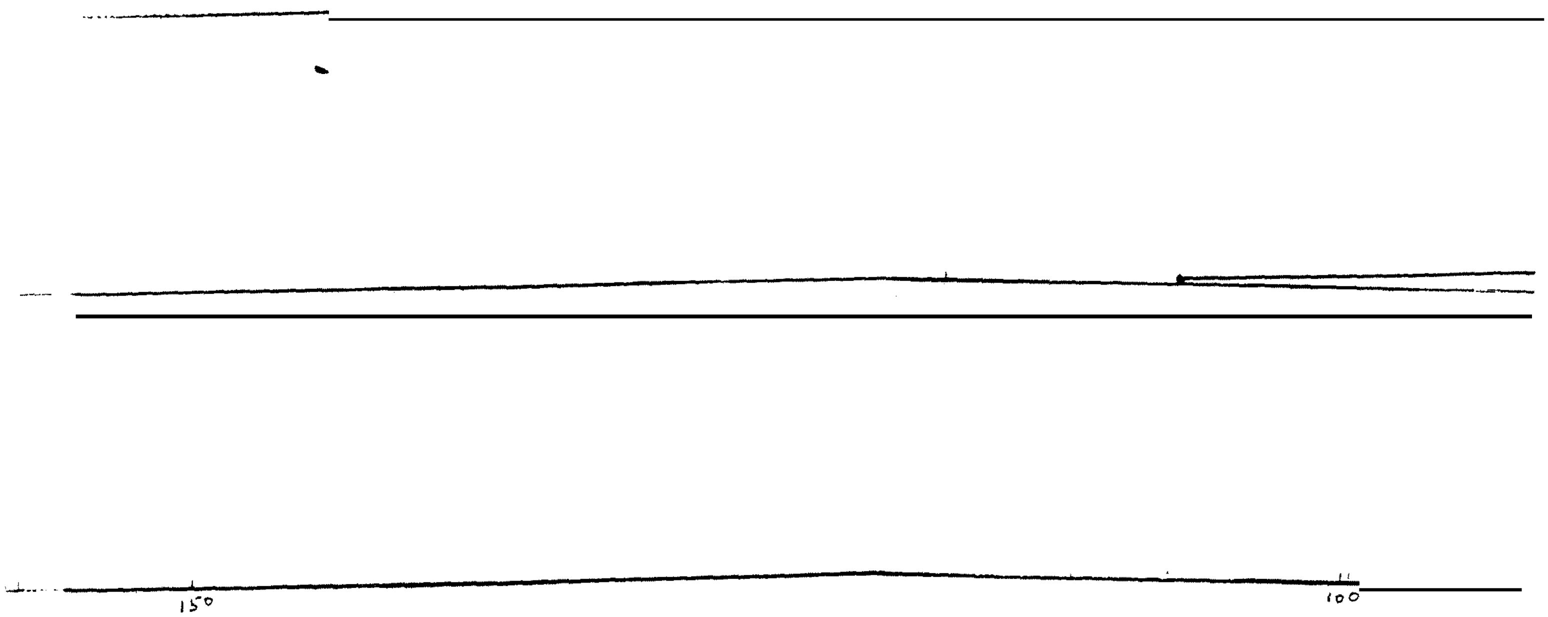


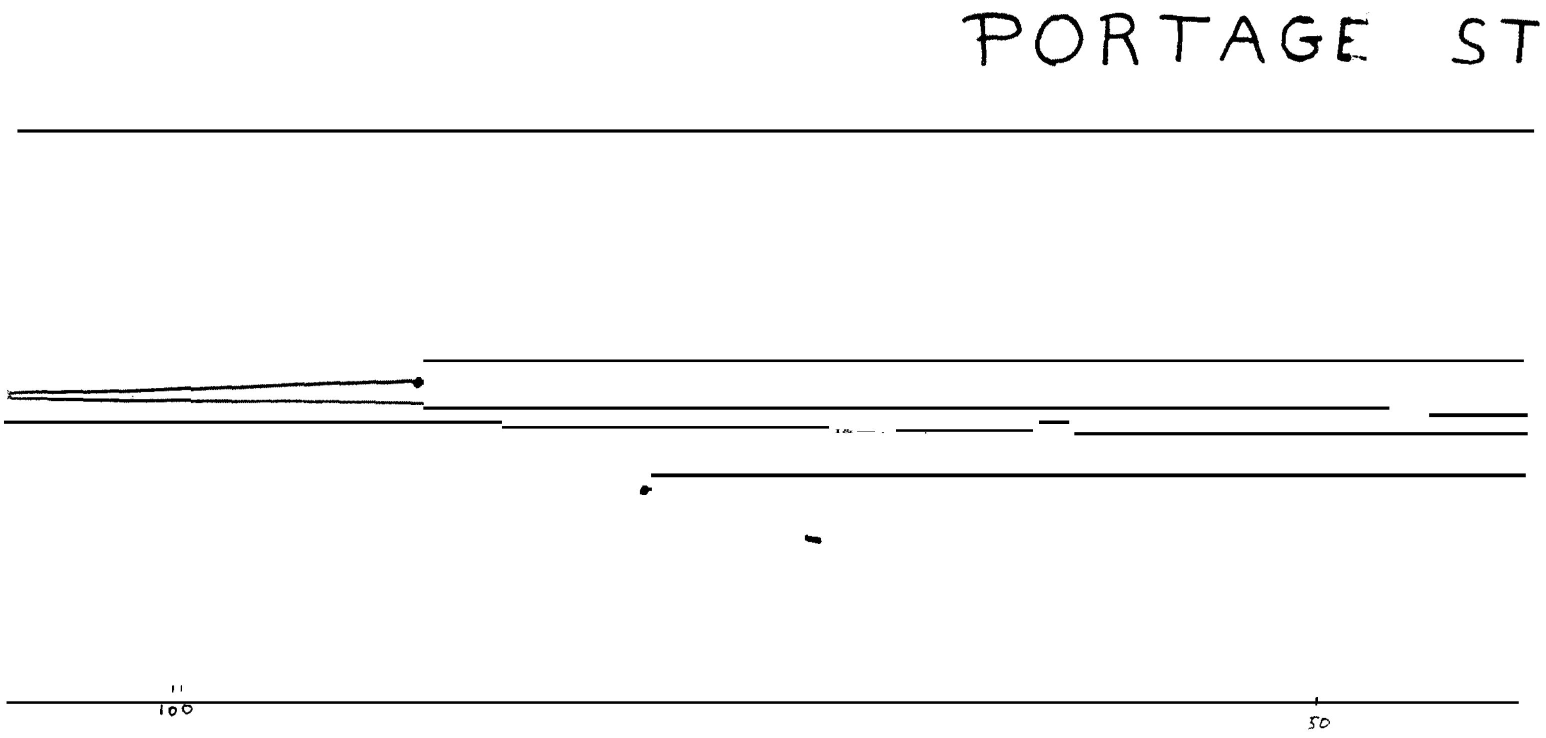
1
I
2
40'
2

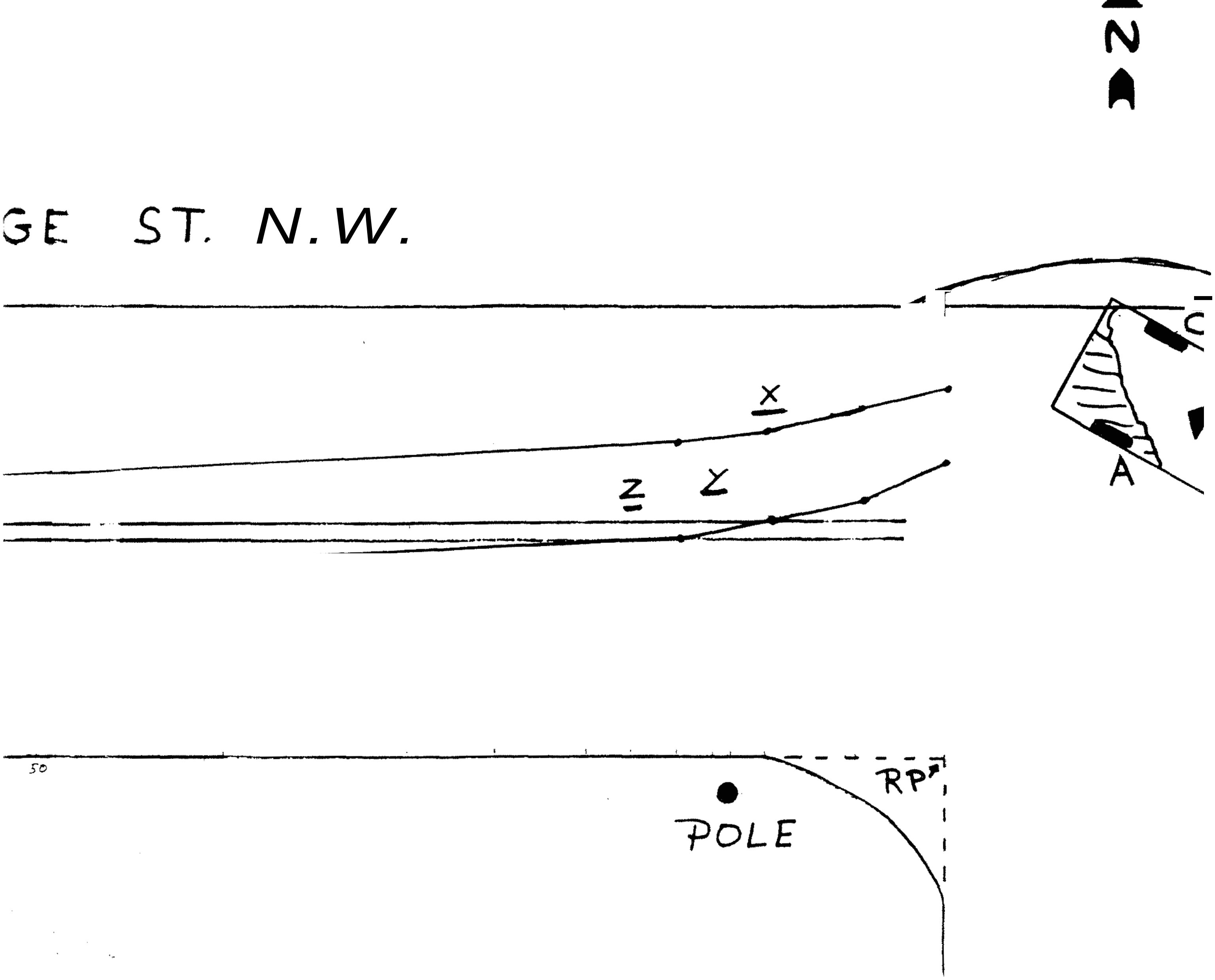

176' from Impact
157' from Impact

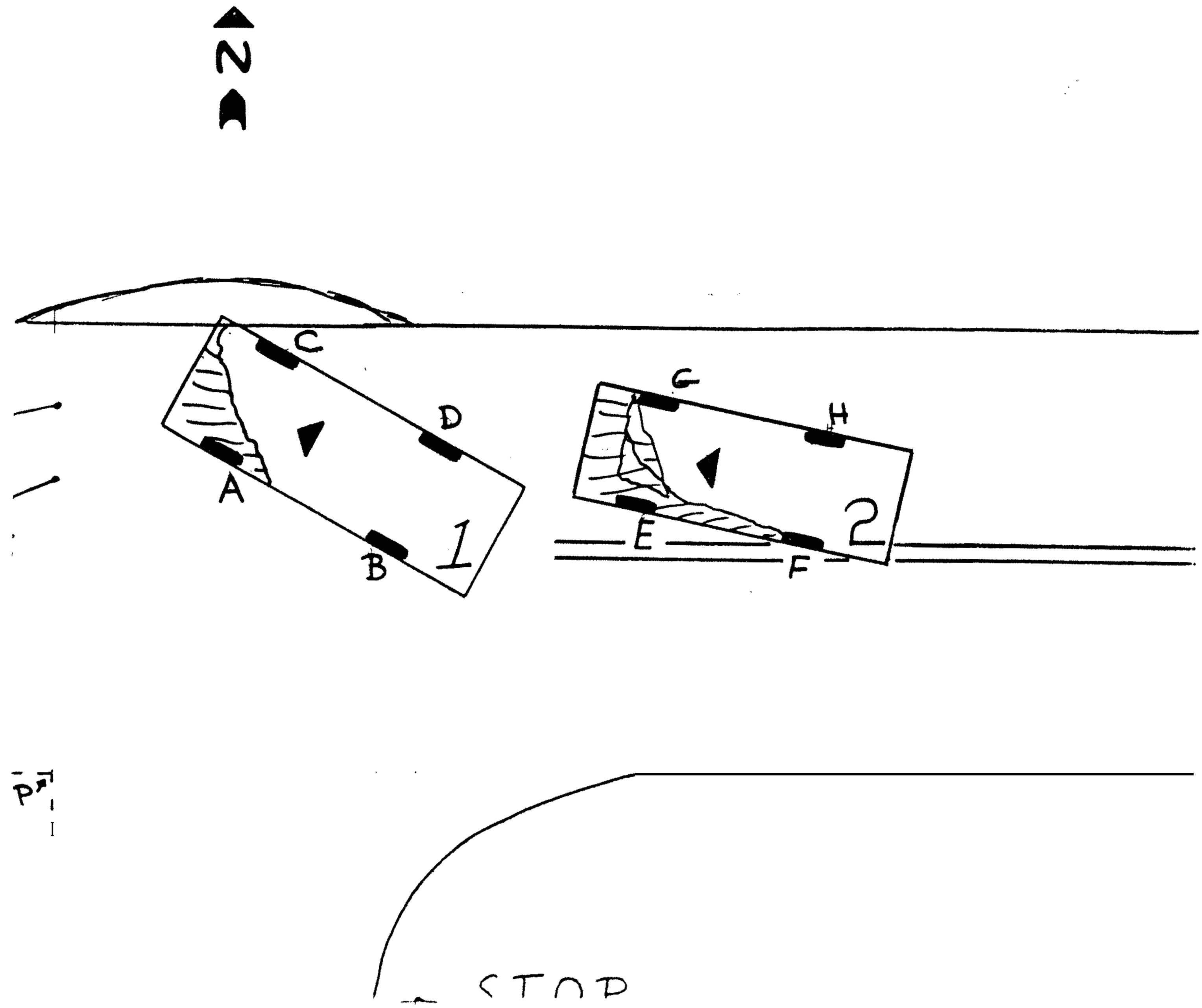

250
200


200
150


150
100


PORTAGE ST
100
50


N
GE ST. N.W.
X
Z
Y
A
50
POLE
RP


N
C
D
A
B
1
G
H
E
F
2
STOP

(#2) Motorcycle rider killed.

Driver of car (#1) cited for illegal turn - prosecuted for vehicular manslaughter.

No skid marks.

Therefore, no evidence that Motorcycle slowed down.

Speed limit sign well east of Hill Crest is 50 mi/hr.

Wow long for #1 to make turn from his lane so he gets across the oncoming lane.

Distance is about 2 carlengths to make a turn.

Turn distance is 32' } Assumption
Take turn at 5 mi/hr }

5 mi/hr = 7.3 ft/sec

$$v = \frac{d}{t}$$

$$7.3 = \frac{32}{t}$$

$$t = \frac{32}{7.3} = 4.38 \text{ sec}$$

Personal experiments

t = 4 sec

Was the driver of #1 committed to the turn before he perceived any danger from the motorcycle?

Experiment at scene

I got on 1 knee at point of impact.
I am then about eye-level with the driver of a car.
I had my wife walk away from me up the hill crest.
Point where I couldn't see her feet was hill crest.
Then found point of which I could no longer see her,
Repeated the experiment having her walk towards me.

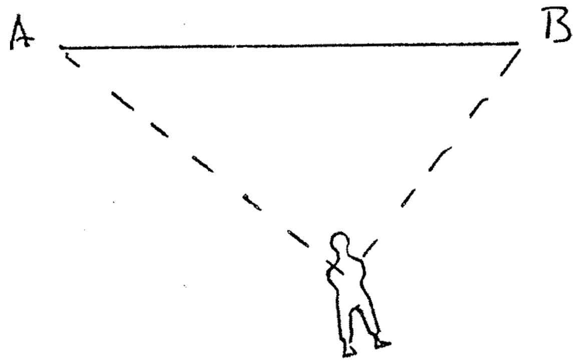
1. Hill crest 286' from point of impact.

2. Point of first possible perception of 4' object 388' from point of impact.

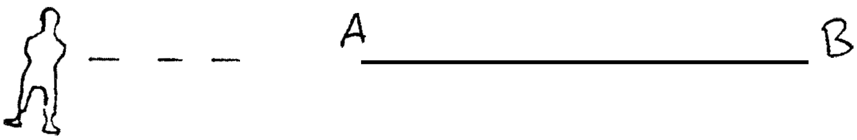
When did driver of car 1st perceive danger?

It is hard to judge speed when a car or motorcycle or anything is coming directly towards you.

Why? To judge speed one needs to estimate a distance divided by a time.



If observer to the side, he can estimate distance from A - B (e.g., between 2 trees and judge the time of travel then $v = \frac{d}{t}$)



Because Depth perception is not good - its harder for us to estimate distances as we look between reference points along our line of vision.

∴ harder to estimate $v = \frac{d}{t}$

Certainly could not judge the speed of the motorcycle until its over the hill crest and on the way down the hill.

Say its 86' over the crest and 200' from point of impact.

(Assumption!)

Now assume Driver of Cycle going various speeds.

	Time to travel 200'
60 mi/hr = 88 ft/sec	2.27 sec
55 mi/hr = 80.7 ft/sec	2.48 sec
50 mi/hr = 73.3 ft/sec	2.72 sec
45 mi/hr = 66 ft/sec	3.03 sec
40 mi/hr = 58.7 ft/sec	3.4 sec
35 mi/hr = 51.3 ft/sec	3.9 sec

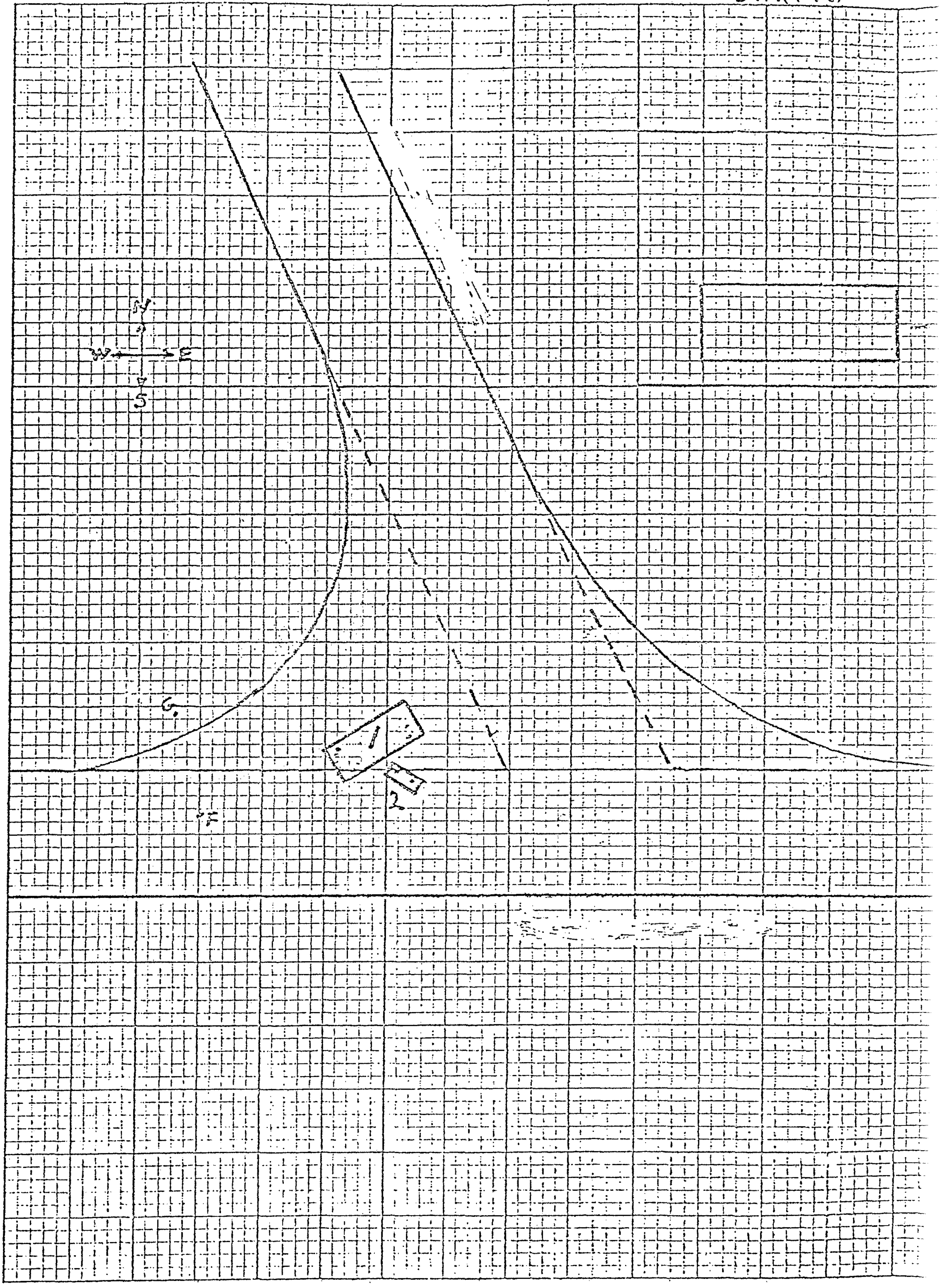
So if car driver perceives danger or a hazard at 200' from point of impact then he is committed to the turn before he perceives the hazard for the above speeds of the motorcycle,

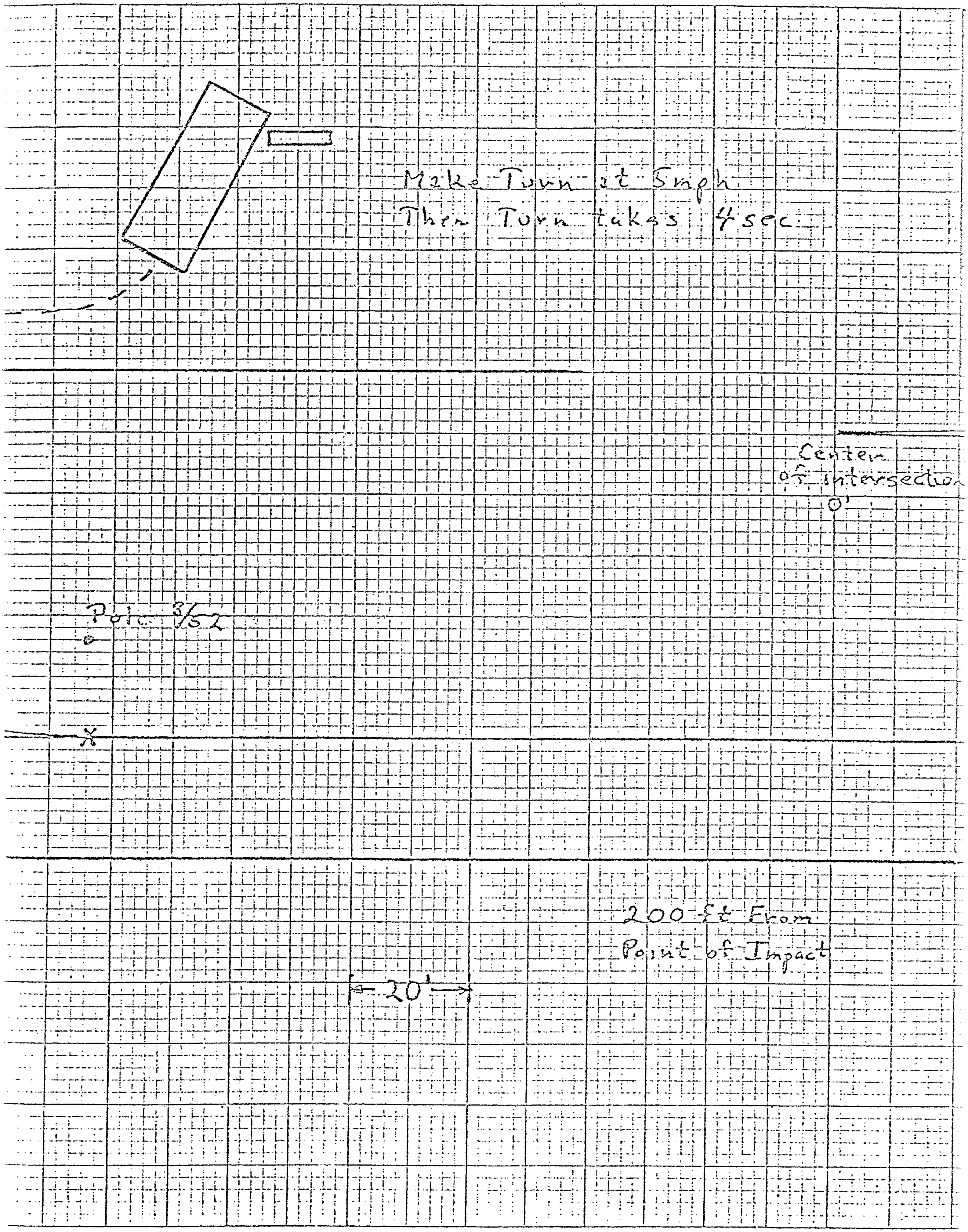
From the damage of the vehicles, can I say who was at fault?

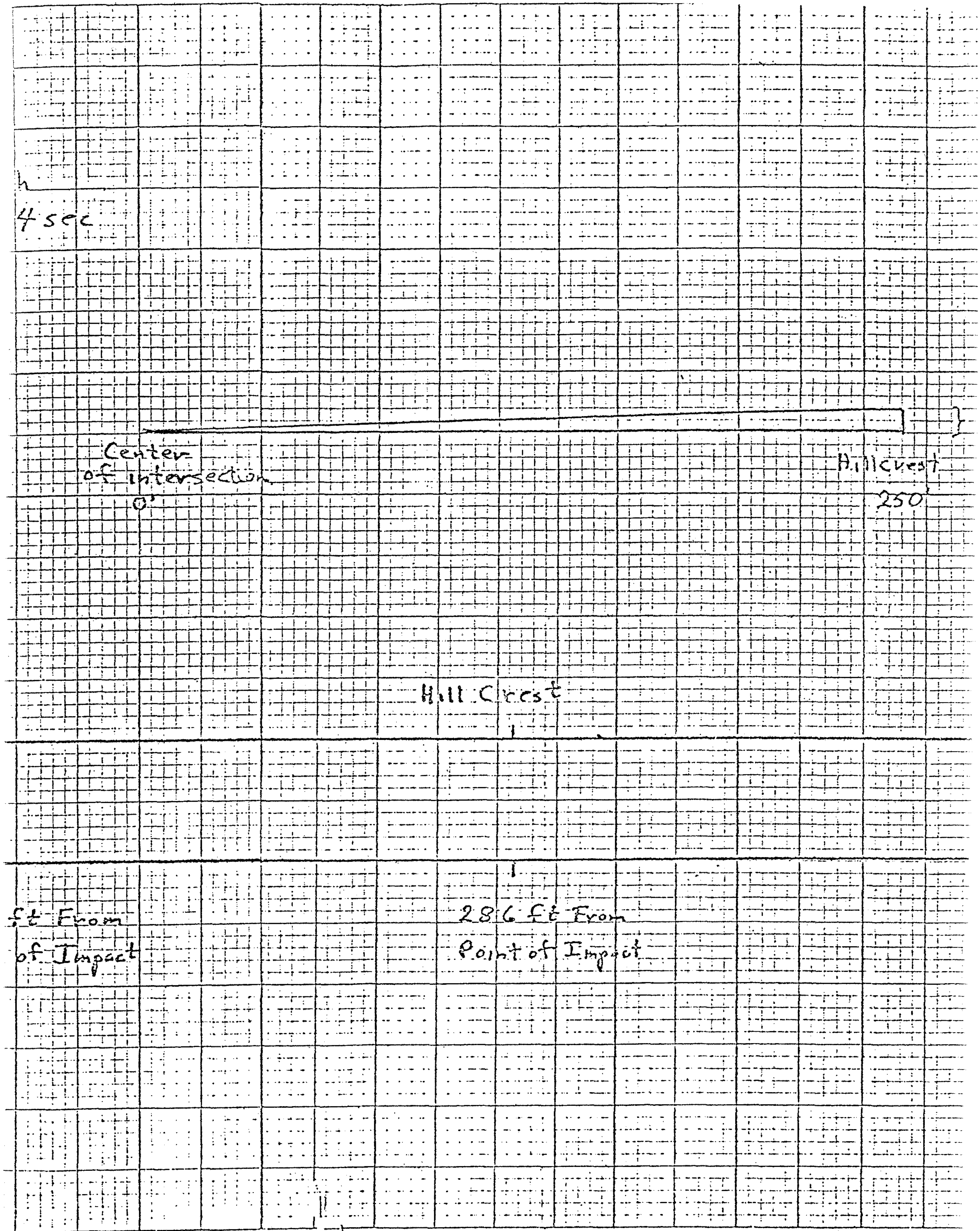
What if the motorcycle had slowed down without skidding?

Is there a reasonable doubt as to the guilt of the driver of the car?

UHRICH




Make Turn at 5mph
Then Turn takes 4sec
Center
of intersection
0'
3/52
200 ft From
Point of Impact
20'



4 sec
Center
of intersection
0'
Hillcrest
250'
Hill Crest
ft From
of Impact
286 ft From
Point of Impact

} 6.28'

$$\frac{6.28}{250} = .025$$

Hillcrest

250

Therefore 2.5% grade

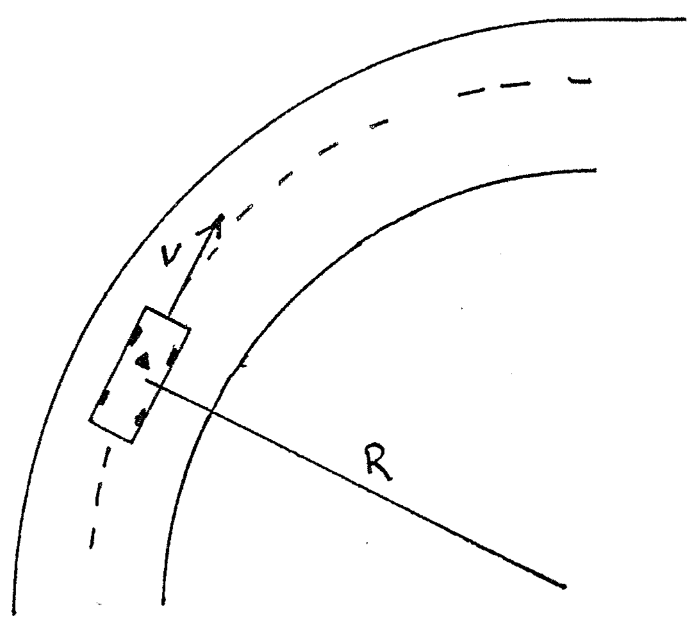
Point of First Sight of a
4 ft high object – From Impact Point

388 ft From
Point of Impact

D.L. Uhrich

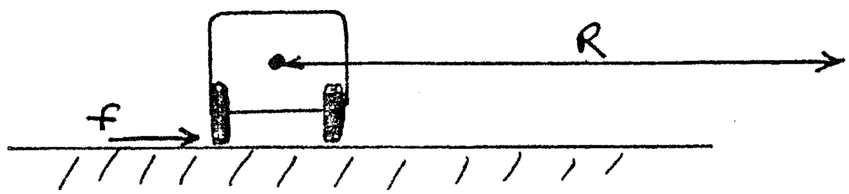
Tip - Over

When a vehicle rounds a curve the force of friction may be sufficient to change the direction of the car's velocity, but there can still be an accident — the vehicle tips or rolls over. The vehicle could be a car, a pick-up or the trailer of a tractor-trailer. Consider the situation depicted below in which a vehicle is rounding a curve to the right:



The vehicle's path is circular with radius R and its speed is v.

If we look at the forces acting on the vehicle we get the following picture



Since the force of friction is the force which causes the vehicle to change the direction of its velocity from Newton's 2nd law we have

$$F_{net} = ma = f$$

but $a = \frac{v^2}{R}$

So $m\frac{v^2}{R} = f$

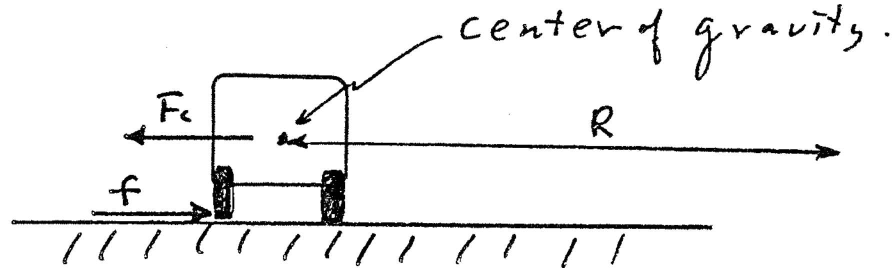
f = friction
m = mass
a = acceleration
v = speed
R = radius of curve

Rewriting this equation we get

$$m\frac{v^2}{R} - f = 0$$

Now it looks like we have an equilibrium situation where $m\frac{v^2}{R}$ and f (friction) balance and we get no motion along the radius R.

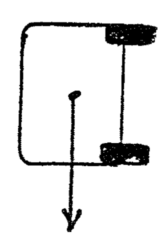
An equivalent way of looking at this situation is



where f is the frictional force and

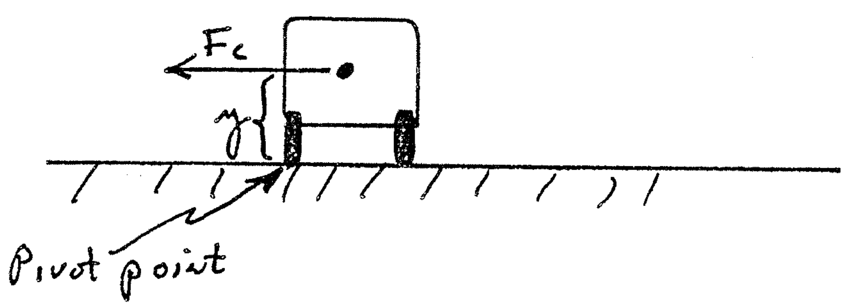
$F_c = mv^2/R$ is called the centrifugal force.

and F_c balances f along the radius.
Notice that the point at which F_c is considered to act is at the center of gravity of the vehicle. Not only midway between the left and right sides of the vehicle but also at the point above the surface at which the entire weight can be considered to act.
Think of the vehicle on its side:



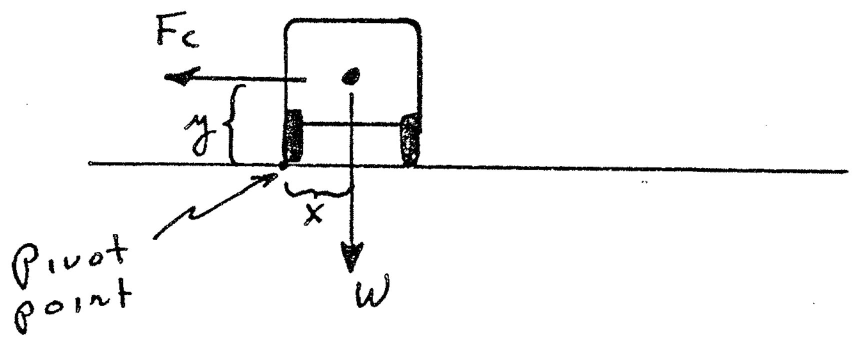
Then the point at which the weight acts (the balance point if we were to hold it up with one finger) is where the weight is considered to act and thus gives us the point above the road surface called the center of gravity or center of mass. The centrifugal force is considered to act at the center of gravity of the vehicle and therefore at a particular height above the ground.

Notice that if friction is able to keep the car from sliding then the centrifugal force tries to tip-over the vehicle. We can consider the left edge of the tire where it contacts the surface as a pivot point.



In other words the centrifugal force exerts a torque about the pivot point and the result of this torque if unbalanced would be a tip-over to the left. The force which seeks to prevent a tip-over is the friendly force of gravity.

Obviously it also acts at the center of gravity and it acts in such a manner as to produce a Torque which opposes the Torque due to the centrifugal force.



Torque is defined as the product of the Force and the perpendicular distance from the pivot to the line of action of the force.

Torque due to F_c = $F_c \; y$ ← vertical height of center of gravity

Torque due to weight W = $W \; x$ ← distance from tire edge to the center of the vehicle

As long as the torque due to the weight <u>exceeds</u> the torque due to the centrifugal force then all is well and there is no tip.

$$W x > F_c y.$$

When the Torque due to the weight is equal to the Torque due to the centrifugal force then the vehicle is on the verge of tipping.

$$W x = F_c y$$

or $$m g x = \frac{m v^2}{R} y$$

Notice the mass appears on both sides and therefore cancels leaving

$$g x = \frac{v^2}{R} y$$

Solving for v:

$$v = \sqrt{R g \frac{x}{y}}$$

This speed is the maximum speed at which the vehicle can negociate the curve without tipping. For any higher speeds the torque due to F_c will exceed the torque due to the weight and the vehicle must tip.

Let $R = 250'$

$x = 4'$ } a loaded trailer
$y = 7'$ }

$g = 32.2 \text{ ft/sec}^2$

$$V = \sqrt{(250)(32.2)\left(\frac{4}{7}\right)}$$

$$V = 67.8 \text{ ft/sec}$$

or

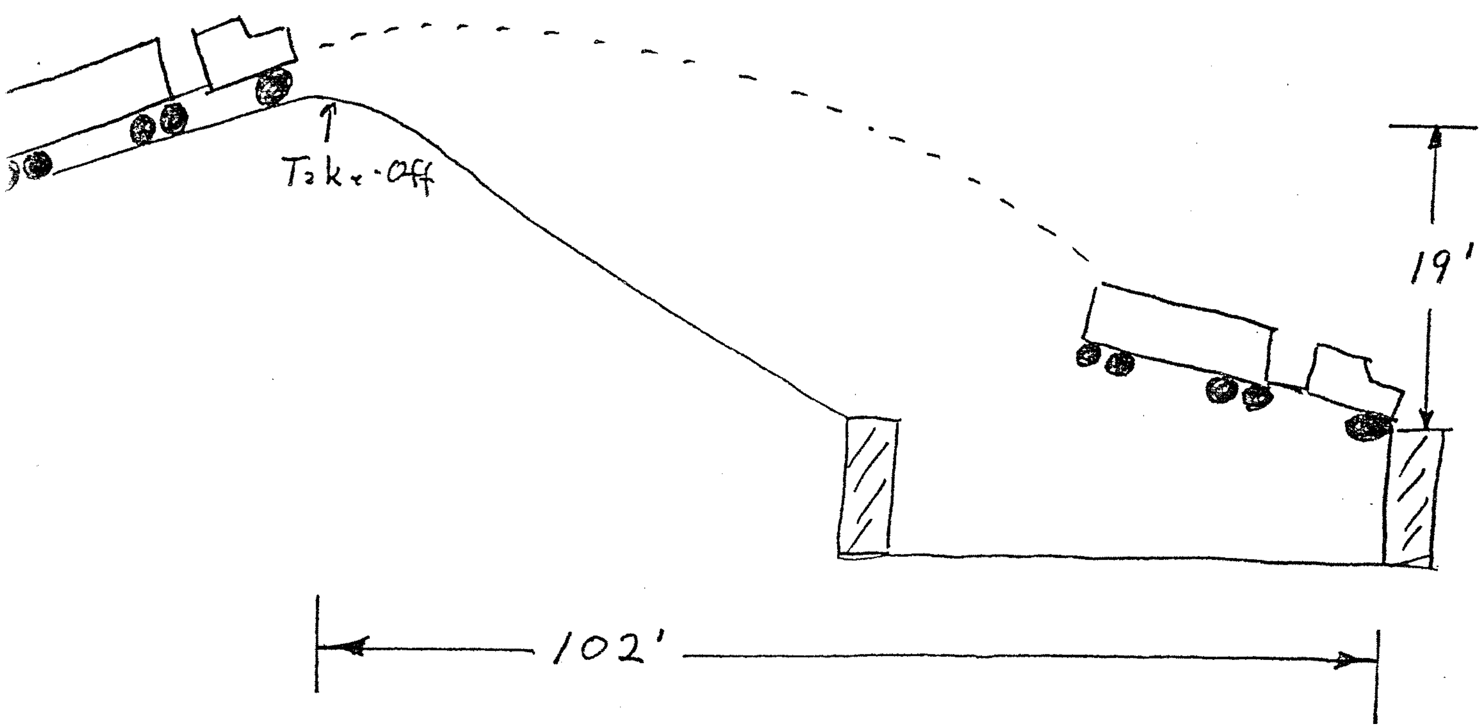
$$V = 46.2 \text{ mph}$$

This speed therefore is the maximum speed at which this trailer can round the curve without tipping <u>or</u> the minimum speed for which tipping will occur.

David L. Uhrich

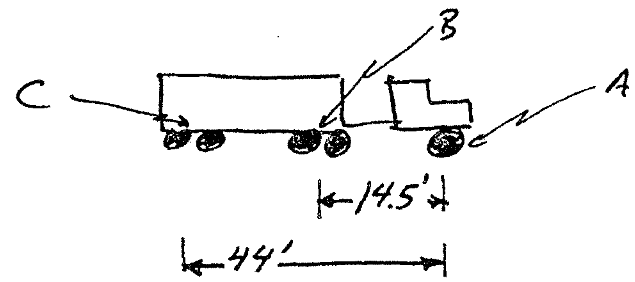
Calculation of a Take-Off Speed

Consider the situation where a semi-tractor-Trailer (or any vehicle for that matter) goes up a slope, becomes airborne and finally hits a wall (or the side of a hill or the ground). The situation is shown below



The horizontal distance from take-off to the point where it hits the wall is 102'. The vertical distance between the take-off point and impact is 19'.

For this problem you have to keep in mind that the weight carried by each axle of the tractor-trailer travels a different horizontal distance while air-borne.



In particular the weight carried by the tractor duals (B) travels 102' − 14.5' = 87.5' in the air and the weight carried by the trailer duals (C) travels 102' − 44' = 58' in the air. As a result, you must somehow account for the fact that the weight carried by the steering axle falls for 102' of horizontal flight; the weight carried by the tractor duals falls for 87.5' of flight; and the weight carried by the trailer duals falls for only 58' of horizontal flight — before hitting. The way these facts are accounted for is by considering the entire weight of the vehicle to act at its center of gravity and to use the horizontal distance traveled by the center of gravity (while airborne).

That is, we need to know the horizontal distance traveled by the center of gravity of the vehicle while the vehicle is falling. The center of gravity (from its name) will be somewhere towards the center of the vehicle – thus by considering its horizontal travel we will be in effect averaging the fall distances for the weights carried by the 3 axles.

Let's consider the following weights carried by the axles:

A	steering axle	9,700 lbs.
B	Tractor duals	32,000 lbs.
C	Trailer duals	32,000 lbs.
		73,700 lbs.

To determine how far to the rear of the steering axle, the center of gravity is we do the following

$$X = \frac{(9{,}700)(0) + 32{,}000(14.5) + 32{,}000(44)}{73{,}700}$$

Center gravity calculation

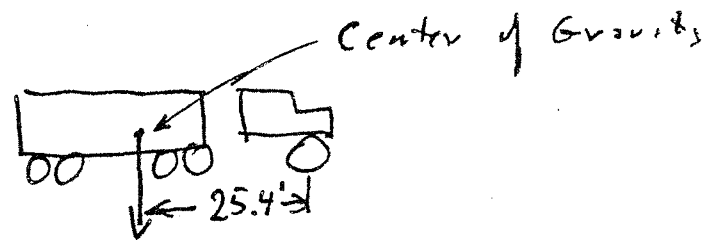
We sum the products of the weights times their distances to the rear of the steering axle. For A – 0'
B – 14.5'

The result is: $X = 25.4'$

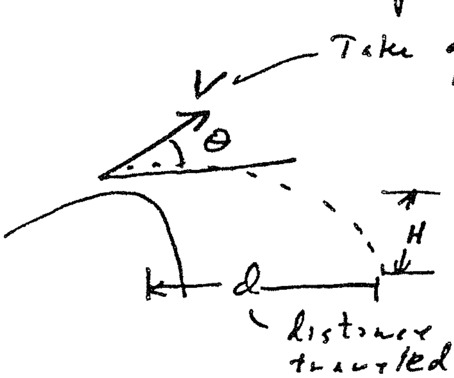
Therefore, we account for the fact that not all of the vehicle weight falls for an horizontal travel of 102' by using:

$$d = 102' - 25.4' = 76.6'$$

as the distance (an average) which we can consider the entire weight of the vehicle to travel horizontally as it falls.



Now we derive the equation for the take-off speed.



The take-off velocity has both a horizontal and a vertical component.

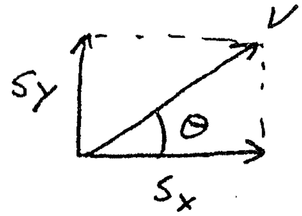
The horizontal problem is described by

$$d = s_x t$$

d = horizontal distance traveled by c. of g.

t = time of flight

s_x = horizontal component of take off speed.



Sx and Sy are the horizontal and vertical component of the take-off velocity V.

$$S_x = V \cos\theta$$
$$S_y = V \sin\theta$$

(1) $\therefore \quad d = (V \cos\theta)\, t$

The vertical problem is one in which the vehicle falls a distance H.

$$H = S_y t - \tfrac{1}{2} g t^2$$

(2) $$H = V \sin\theta\, t - \tfrac{1}{2} g t^2$$

g = the acceleration due to gravity (32.2 ft/sec²)
t = the time of flight.

Since t in (1) and (2) is the same then we can solve (1) for t and plug that into (2)

From (1) $\quad t = \dfrac{d}{V\cos\theta}$

Putting this into ② we get.

$$H = V\sin\theta\left(\frac{d}{V\cos\theta}\right) - \frac{1}{2}g\left(\frac{d}{V\cos\theta}\right)^2$$

This becomes

$$H = d\,\frac{\sin\theta}{\cos\theta} \quad \frac{1}{2}g\,\frac{d^2}{V^2\cos^2\theta}$$

$$\frac{\sin\theta}{\cos\theta} = \tan\theta$$ and $\tan\theta = \%$ grade given as a decimal

Therefore

$$H = d\tan\theta - \frac{1}{2}g\,\frac{d^2}{V^2\cos^2\theta}$$

For take-off angles less than 25°

$\cos^2\theta$ is very nearly 1

Therefore

$$H = d\tan\theta - \frac{1}{2}g\,\frac{d^2}{V^2}$$

Now we can solve for the take-off speed V in terms of H, d and $\tan\theta$.

$$H = d \tan\theta - \frac{1}{2} g \frac{d^2}{v^2}$$

Subtract $d \tan\theta$ from each side.

$$H - d \tan\theta = -\frac{1}{2} g \frac{d^2}{v^2}$$

Change the sign of the equation.

$$+ d \tan\theta - H = \frac{1}{2} g \frac{d^2}{v^2}$$

Multiply both sides by v^2

$$v^2 (d \tan\theta - H) = \frac{1}{2} g \frac{d^2 \, v^2}{\cancel{v^2}}$$

Divide both sides by $(d \tan\theta - H)$

$$v^2 \left(\cancel{\frac{d \tan\theta - H}{d \tan\theta - H}} \right) = \frac{g}{2} \frac{d^2}{(d \tan\theta - H)}$$

Take the square root of each side

$$v = \frac{\sqrt{g/2} \quad d}{\sqrt{d \tan\theta - H}}$$

$$\sqrt{g/2} = \sqrt{\frac{32.2}{2}} = \sqrt{16.1} = 4.01$$

Therefore: $$v = \frac{4.01\ d}{\sqrt{d(\%\text{grade}) - H}}$$

Here you have to note that if the point at which the vehicle hits is lower than the take-off point then H is a negative number. If it is above the take-off point it is a positive number.

Going back to our problem of the semi

$H = -19'$
$d = 102' - 25.4' = 76.6'$
% grade = 4% = .04 (assume a 4% take off grade)

Then $$v = \frac{(4.01)(76.6)}{\sqrt{(76.6)(.04) - (-19)}}$$

−x− yields +

so

$$v = \frac{(4.01)(76.6)}{\sqrt{(76.6)(.04) + 19}}$$

$$\boxed{v = 65.4\ \text{ft/sec} = 44.6\ \text{mph}}$$

Notice that if we ignored the fact that the vehicle was extended and that the weight carried by each axle did not travel the same horizontal distance while airborne we would have:

$d = 102'$

$H = -19'$

$\%grade = .04$

$$V = \frac{(4.01)(102)}{\sqrt{(.04)(102) - (-19)}}$$

V 85 ft/sec = 58 mph ↑

This answer, however, is absolutely wrong.

The books have

$$V = \frac{2.73\ d}{\sqrt{S d - H}}$$

S = % grade or slope.

where the answer comes out in mph

$4.01\left(\frac{60}{88}\right) = 2.73$ just represents the conversion from ft/s to mph.

Dry travelled asphalt

Assume speed greater than 30 mph

Coefficient of friction = 0.55 — 0.70

Skid distance = 80 ft

Assume a horizontal surface

Assume all four wheels lock

Assume car skids to a stop

KE = Work done against friction

$\frac{1}{2}mv^2 = \mu mgd$

μmg → friction force

d → distance through which it acts (skid distance)

m's cancel

so $\frac{1}{2}v^2 = \mu gd$

$v^2 = 2\mu gd$

$\mu = .55$ $\quad v^2 = 2(.55)(32)(80)$

$v^2 = 2816$

$v^2 = 53 \times 53$

$v = 53$ ft/sec

$v = \frac{53}{1.47} = 36.1$ mi/hr

$\mu = .70$ $\quad v^2 = 2(.70)(32)(80)$

$v^2 = 3584$

$v^2 = 59.9 \times 59.9$

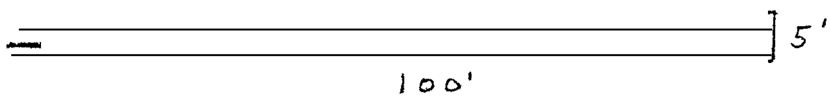
$v = 59.9$ ft/sec

$v = \frac{59.9}{1.47} = 40.7$ mi/hr

Possible speeds

v = 36 - 41 mi/hr

Same problem except the car skids to a stop on a 5% grade



$\frac{1}{2}mv^2 = (\mu \pm \%grade)mgd$

This is a decimal and equal to the sin θ where θ is the angle of the grade

m's still cancel

so $v^2 = 2(\mu \pm \%grade)gd$

Skid uphill

$\mu = .55$ $v^2 = 2(\mu + \%grade)gd$

$v^2 = 2(.55 + .05)gd$

$v^2 = 2(.60)(32)(80)$

$v^2 = 3072$

v = 55.4 ft/sec

v = 37.7 mi/hr

$\mu = .70$ $v^2 = 2(.70 + .05)(32)(80)$

$v^2 = 3840$

v = 62 ft/sec

v = 42.2 mi/hr

Possible speeds

v = 37.7 - 42.2 mi/hr

greatest speed assume skid uphill

Same problem except car skids to a stop on a 5% downhill grade

$\frac{1}{2}mv^2 = (\mu - .05)mgd$

m's still cancel

$\mu = .55$ $\quad v^2 = 2(\mu - .05)gd$

$v^2 = 2(.5)(32)(80)$

$v^2 = 2560$

$v = 50.6$ ft/sec

$v = 34.4$ mi/hr

$\mu = .70$ $\quad v^2 = 2(.65)gd$

$v^2 = 2(.65)(32)(80)$

$v^2 = 3328$

$v = 57.7$ ft/sec

$v = 39.2$ mi/hr

Range of speeds

$v = 34 - 39$ mi/hr

Speed Range:

Level Road	36 - 41 mi/hr
5% uphill grade	37.7 - 42.2 mi/hr
5% downhill grade	34 - 39 mi/hr

NB

% grade has a greater effect as one goes to lower values of μ.

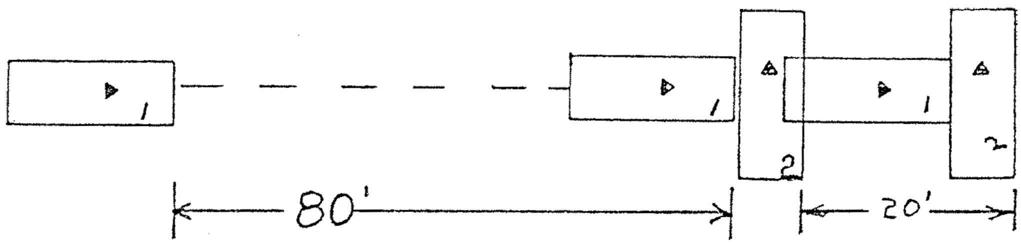
But very Impor what type of road

Condition factor

Skid distance 80 ft for Car #1

Coefficient of friction 0.55 - 0.70

Assume (again) dry travelled asphalt and a speed greater than 30 mph



Car #1 hits car #2 and both slide (stuck together) for 20'

Compute speed of #1 ami #2 the instant after the collision

$$\tfrac{1}{2}(m_1 + m_2)v^2 = \mu(m_1 + m_2)gd$$

Kinetic Energy — Work against Friction

$$v^2 = 2\mu gd$$

$\mu = .55$ $\quad v^2 = 2(.55)(32)(20)$

$$v^2 = 704$$

$v = 26.5$ ft/sec (18.1 mi/hr)

$\mu = .70$ $\quad v^2 = 2(.70)(32)(20)$

$$v^2 = 896$$

$v = 29.9$ ft/sec (20.4 mi/hr)

Speed range

$v = 18.1 - 20.4$ mi/hr

Conservation of Momentum
in the collision

Before		After

$$m_1 v_1 + m_2(0) = (m_1 + m_2)v$$

velocity of 1 before collision (at end of 80' skid.)	velocity of 2 before collision	velocity of combination after the collision

Say $m_1 g = 3000$ lbs

$$m_1 = \frac{3000}{32}$$

$m_2 g = 4000$ lbs

$$m_2 = \frac{4000}{32}$$

$$\frac{3000}{32}v_1 + 0 = \left(\frac{3000}{32} + \frac{4000}{32}\right)v$$

$$3v_1 = 7v$$

$$v_1 = \frac{7}{3}v$$

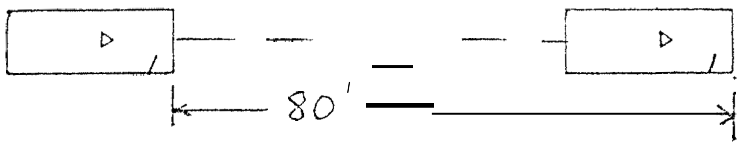
$\mu = .55$ $v = 26.5$ ft/sec

$v_1 = \frac{7}{3}(26.5) = 61.8$ ft/sec (43.2 mi/hr)

$\mu = .70$ $v = 29.9$ ft/sec

$v_1 = \frac{7}{3}(29.9) = 63.8$ ft/sec (47.6 mi/hr)

Consider 80' skid of #1



$KE_{initial} = W_{work\ against\ friction} + KE_{end\ of\ skid}$

$\frac{1}{2}m_1v^2_{initial} = m_1\mu gd + \frac{1}{2}m_1v_1^2$

$\mu = .55$

$v_1 = 61.8$ ft/sec (42.1 mi/hr)

$\frac{1}{2}v^2_{initial} = (.55)(32)(80) + \frac{1}{2}(61.8)^2$

$v^2_{initial} = \underline{2816} + \underline{3819}$

$v_{initial} = 81.5$ ft/sec

$v_{initial} = 55.5$ mi/hr lower limit

$\mu = .70$

$v_1 = 69.8$ ft/sec (47.6 mi/hr)

$\frac{1}{2}v^2_{initial} = (.70)(32)(80) = \frac{1}{2}(69.8)^2$

$v^2_{initial} = \underline{3584} + \underline{4872}$

$v_{initial} = 91.9$ ft/sec

$v_{initial} = 62.7$ mi/hr

Range of speeds:

55 - 63 mi/hr

Speed range = .55 - .70

80' skid no collision

36 - 41 mi/hr

speed range

80' skid + collision with a heavier car + both slide an additional 20'

55 - 63 mi/hr

Situation

Both car #1 and car #2 are headed north. Car #1 starts to move from the curb lane to the passing lane. As he starts to change lanes he sees car #2 coming in the left lane. Car #1 then swerved back into the curb lane, ran over the curb, and swerved back into the curb lane and struck the right rear corner of car #2 with the left front fender. Car #2 began "broadsiding" and made a quarter clockwise turn and slammed into the utility pole (E). Car #1 on contact made a half' clockwise turn and ended up in the center of the northbound lanes facing south.

Data

1. Damage to left front of car #1.
2. Damage to right rear of car #2.
3. Damage to left side of car #2.
4. Broadside skid marks of car #2 showing that it skidded 123 feet before hitting pole E.
5. Position of car #1 after impact shows that it traveled 125 feet after impact. No skid marks from car #1 were shown in the police report or in photographs of the scene.
6. Both cars spun clockwise after the impact.

Charge

The driver of car #1 was charged with vehicular manslaughter. The prosecution contended that car #2 was traveling straight in the passing lane northbound and that the impact caused it to spin, cross the curb lane, and hit the pole. The driver of car #2 was killed.

In addition to the above, a police officer skidded a patrol car at the accident intersection and measured a drag factor of 1.18. Using this drag factor, he computed that both cars were traveling in excess of 60 miles/hour at impact. The speed limit was 35 miles/hour.

Results of the Accident Reconstruction Using the Proper Physics

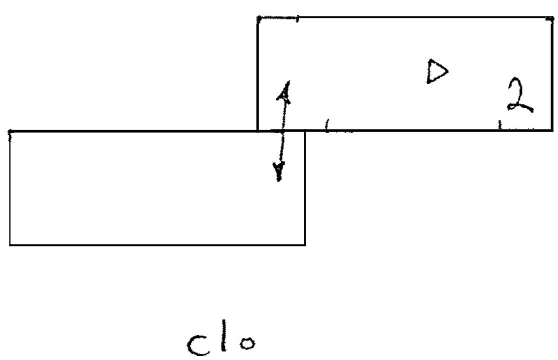
1. Car #2 was not traveling straight in the passing lane. Rather, he was heading towards the curb lane. In fact, the angle was more severe than the angle car #2's skid marks make with the northbound direction. The reason for this conclusion is that the clockwise rotation of both cars proves that car #2 must have been deflected to the left of its direction before impact. Also, car #1 must have been deflected to the right of its direction before impact.

2. The drag factor of 1.18 which was measured by tine police officer is completely unreasonable. The possible values of the coefficient of friction for dry asphalt are given by the Traffic Accident Investigation Manual as falling in the range 0.45 - 0.70. The % uphill grade of the accident road is 7.96%. Thus, the drag factor lies in the range

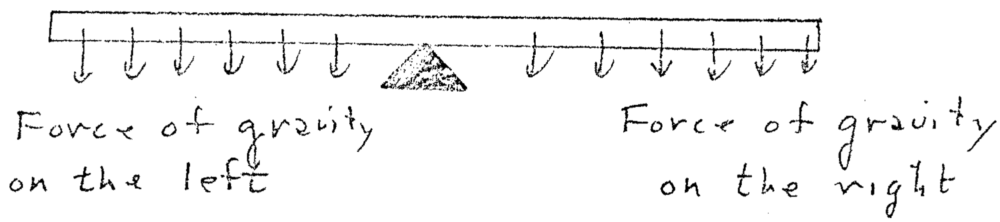
   0.5296 - .7796

   As a result, the officer's Computations of tne speeds were wrong and in each case gave a value which was too high.

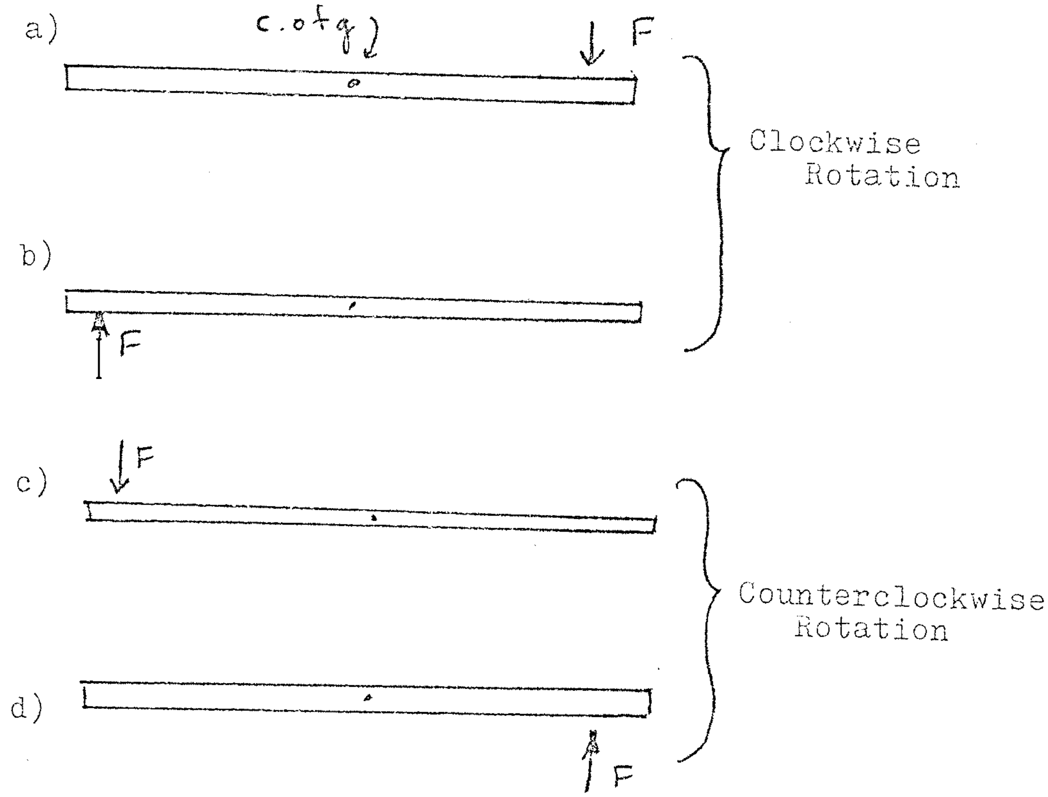
Main Steps in the Analysis



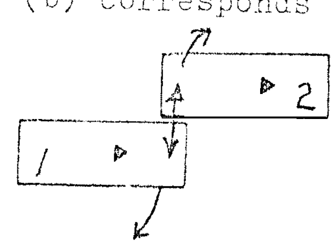
The center of gravity of an object (ruler, pencil, or car) is the paint where one can balance tne object. When the object is balanced at this point, the force of gravity on the mass to the left of the point is exactly balanced by the force of gravity on the right of this point.



If you place this object on a flat surface and push as is shown in the following diagrams, you intuitively know which way the object will rotate.



Notice that for case (a) the initial direction of motion of the c. of g. is downward. Further, for case (b) the initial direction of motion of the c. of g. is up. Case (a) corresponds to car #1 and case (b) corresponds to car #2 in the present accident.



The center of gravity of an object (ruler, pencil, car, etc.) will travel in a straight line once the object begins to skid or slide. Any rotation that occurs will be about the center of gravity and not affect the direction of the straight line motion. Recall what happened when you fell the first time you were on ice skates. Also, give your pencil a spin just as you push it across your desk. It spins, but still travels in a straight line.

Here, car #2 is hit in the right rear and its c. of g. begins a clockwise rotation pivoting about the right front wheel. Thus, after impact the direction of notion of the c. of g. is initially to the left of the direction of motion before impact. Then all four tires begin skidding and car #1 must continue traveling in the direction of motion that the c. of g. had when the pivot wheel begins sliding. As a result, the direction of #2's skid is to the left of its initial direction of motion at impact. The net result is that car #2 must have been headed cross-lane towards the east curb before impact. By similar arguements, car #1 was deflected to the right of its direction of motion before impact,

2. Speed - Vehicle #2

drag factor 0.5296 - 0.7796
skid distance 123' (skid narks plus evidence of a broadside skid)
final speed of car #1 (i.e., speed at which it hit the pole E) 10 - 30 mph

$$KE_{after\ impact} = W_{work\ against\ friction\ and\ uphill\ grade} + KE_{at\ pole}$$

$$\frac{1}{2}\not{m}v_2^{\,2} = \mu\not{m}gd + \frac{1}{2}\not{m}v^2_{pole}$$

$$v_2^{\,2} = 2\mu gd + v^2_{pole}$$

Calculated speed range 45.5 ↔ 61.6 mph for v_2.

3. <u>Speed</u> - Vehicle #1

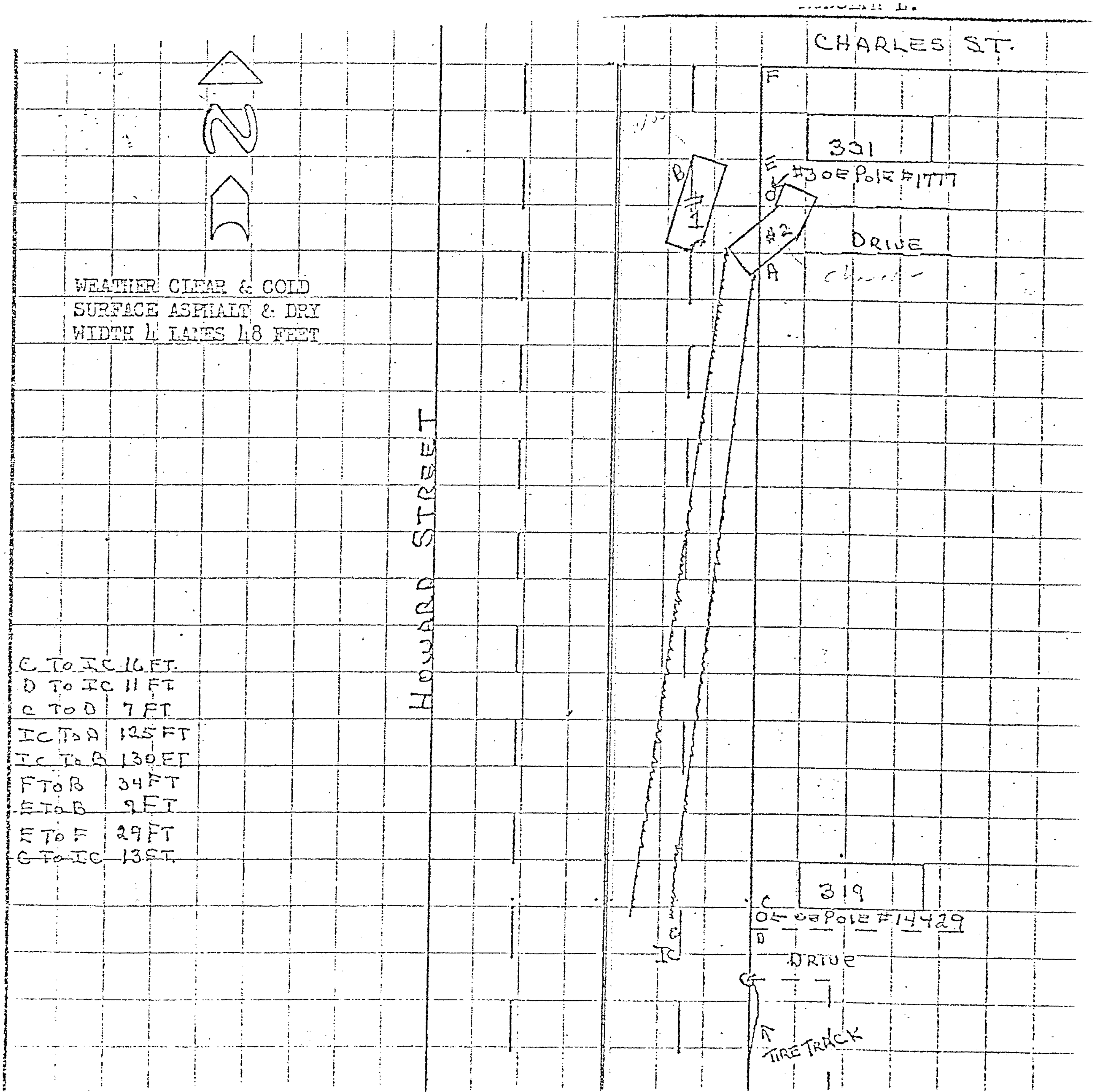
drag factor 0.5296 - 0.7796
skid distance ?

Since there were no skid marks after the 180°
rotation, the car may have rolled backwards up the hill.

Using various conditions, one obtains several possible results.

	Speed range of #1
1. 4 wheels lock for a 125 foot skid to a stop	44 ↔ 53 mph
2. 180° spin in 15 ft. all wheels locked then a 55 ft. skid with all wheels locked and a 55 ft. roll to a stop	31 ↔ 40 mph
3. 180° spin in 15 ft. with all wheels locked. Then a 110 ft. skid with 2 locked wheels and 2 wheels braking at ½ efficiency	38 ↔ 47 mph

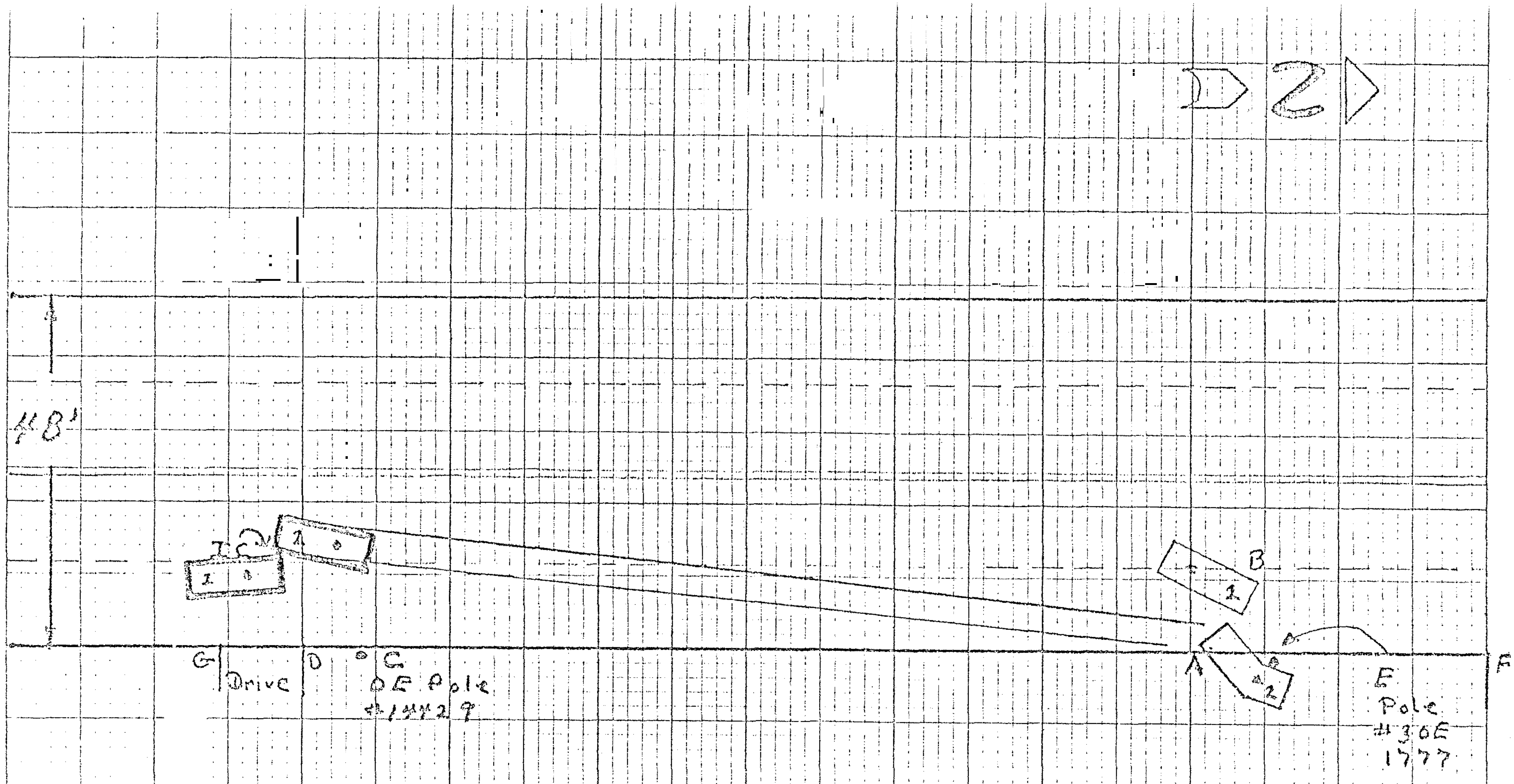
VII



OFFICER'S SIGNATURE

ID NUMBER

2

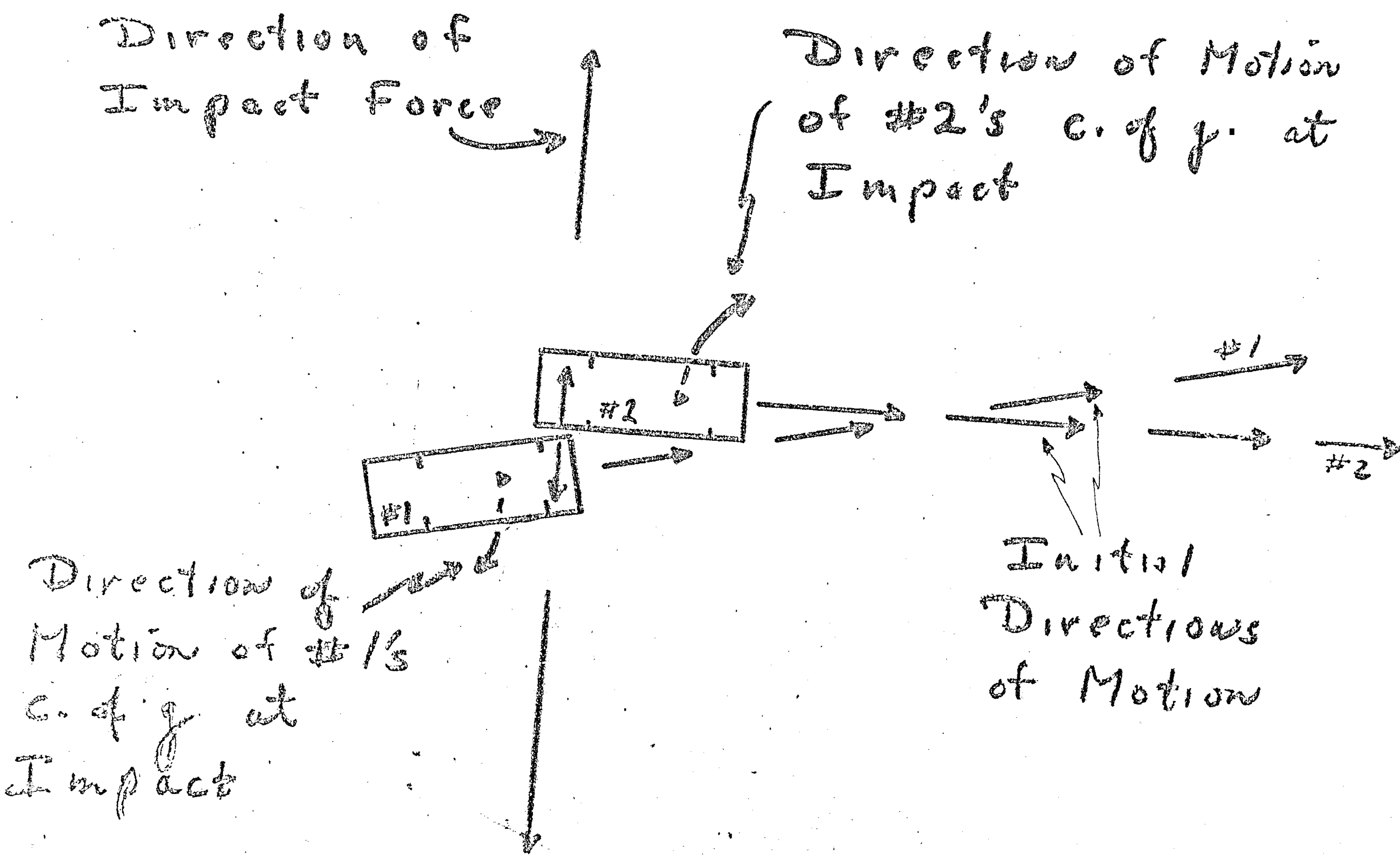


IC - A 125'

IC - B 130'

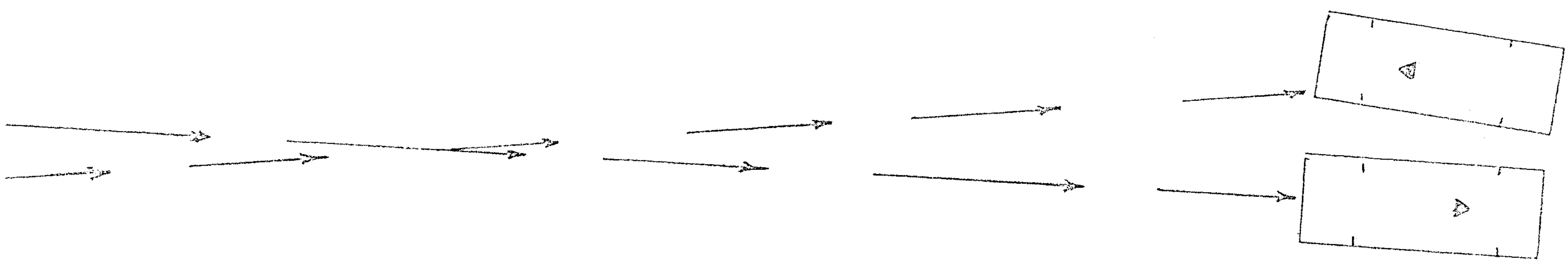
After Impact c of g. of #1 moved 125'
c of g. of #2 moved 125'

UHRICH


Direction of Impact Force
Direction of Motion of #2's c. of g. at Impact
#2
#1
Direction of Motion of #1's c. of g. at Impact
Initial Directions of Motion
#1
#2

Final Directions of Motion when all four wheels of each car begin to skid

#1 is deflected to the right



#2 is deflected to the left