LOS ANGELES POLICE DEPARTMENT

INTERMEDIATE COLLISION INVESTIGATION

January 2005

INTERMEDIATE COLLISION INVESTIGATION SCHEDULE

TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
0700 0750	COURSE INTRO & OVERVIEW	MATH REVIEW COMPLETED QUIZ #1	DRAG FACTOR & GRADE Topic 5.0	TIME / DISTANCE Topic 6.0	GROUP PROJECT CASE STUDIES
0800 0850	TIREMARKS & PHYSICAL EVIDENCE Topic 2.0	EVIDENCE DOCUMENTATION Topic 4.0		FIELD EXERCISE SKID TESTING & DRAG SLED TESTS	
0900 0950			SPEED COMPUTATION Topic 6.0		
1000 1050	MATH REVIEW Topic 3.0				
1100 1130	LUNCH	LUNCH	LUNCH	LUNCH	LUNCH
1130 1530	MATH REVIEW CONTINUED Topic 3.0	SKID DOCUMENTATION FIELD PROBLEM	SPEED COMPUTATION CONTINUED Topic 6.0	SKID DOCUMENTATION & SPEED COMPUTATION FIELD PROBLEM	CASE STUDIES CONTINUED COURSE REVIEW FINAL EXAM
NOTES	SKILL ASSESSMENT	QUIZ #1 -10 PTS FIELD PROBLEM – 20 PTS		FIELD PROBLEM – 20 PTS	FINAL EXAM – 50 PTS

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EQUATION SHEET

TO FIND	WHEN GIVEN			EQUATION TO USE	
ACCELERATION (a) (feet per second^2)	t	v_i	v_e	1.	$a = \frac{v_e - v_i}{t}$
	t	v_i	d	2.	$a = \frac{2d - 2v_i t}{t^2}$
	v_i	v_e	d	3.	$a = \frac{v_e^2 - v_i^2}{2d}$
INITIAL VELOCITY (v_i) (feet per second)	t	a	v_e	4.	$v_i = v_e - at$
	t	a	d	5.	$v_i = \frac{d}{t} - \frac{at}{2}$
	a	v_e	d	6.	$v_i = \sqrt{v_e^2 - 2ad}$
END VELOCITY (v_e) (feet per second)	t	a	v_i	7.	$v_e = v_i + at$
	a	v_i	d	8.	$v_e = \sqrt{v_i^2 + 2ad}$
DISTANCE (d) (feet)	t	a	v_i	9.	$d = v_i t + \frac{1}{2}at^2$
	a	v_i	v_e	10.	$d = \frac{v_e^2 - v_i^2}{2a}$
	t	v_i	v_e	11.	$d = \frac{t(v_i + v_e)}{2}$
TIME (t) (seconds)	a	v_i	v_e	12.	$t = \frac{v_e - v_i}{a}$

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COURSE INTRODUCTION AND OVERVIEW

DEFINITIONS

TOPIC 1.0

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

The intermediate Collision Investigation Course was designed to provide police officers additional, specialized knowledge of identification and documentation of physical evidence and speed computation procedures.

The goals of this course are to provide you, the student:

- With the knowledge and skills necessary to effectively conduct collision investigations through proper physical evidence identification and documentation.
- With the knowledge and skills necessary to use that physical evidence to estimate a minimum speed for the vehicles involved in the collision.

During this course you will:

- Understand the definitions and terminology used in the field of traffic collision investigation and reconstruction.
- Accurately identify and document different types of physical evidence.
- Identify the basis for each numeric component of speed estimate equations.
- Estimate the minimum speeds of vehicles based on physical evidence commonly encountered at traffic collisions.
- Complete time and distance calculations to determine position and sight line for drivers based on your speed estimates.

An outline of the course is presented on the next page. The course will use a mix of classroom instruction, group learning activities, and field projects. You participation is paramount to the success of the course and will allow you to get the most benefit.

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COURSE OUTLINE

TOPIC NO.	CLASS	OBJECTIVE
1.0	INTRODUCTION & TERMINOLOGY	Present definitions of terminology used in traffic collision investigation and reconstruction
2.0	TIRE MARKS	Identification of different tire mark types, identification of other evidence. Photography review
3.0	MATH REVIEW	Present basic algebraic processes
4.0	PHYSICAL EVIDENCE DOCUMENTATION	Review physical evidence location and documentation procedures
5.0	DRAG FACTOR	Define the term "Drag Factor" and the different factors that effect the coefficient of friction of the roadway
6.0	SPEED COMPUTATION	Present the different methods of speed calculation based on physical evidence with the use of accepted equations
7.0	CASE STUDIES	Provide practical application in the use of the equations taught in Topic 6.0

I. DEFINITIONS AND TERMINOLOGY

A. ACCELERATION (a)

The rate of change of velocity with respect to time. Acceleration may be either a positive value (acceleration), or a negative value (deceleration).

B. CHORD (C)

A straight line connecting two points on an arc.

C. COEFFICIENT OF FRICTION OR MU (f or μ)

A number, expressed as a decimal, representing the resistance of an object sliding on a level surface.

D. DISTANCE (d)

A measurement between two points which can be expressed in any increment of measure (inches, meters, etc.). Generally will be expressed in decimal feet for this class.

E. ENDING VELOCITY (v_e)

An ending rate of motion during any change of position with respect to time. Can be expressed in any value of motion (miles per hour, meters per second, etc.). Expressed in feet per second for this class.

F. ENERGY (E)

The capacity to do work. There are various types of energy:

1) Potential Energy

2) Kinetic Energy

3) Heat Energy

4) Light Energy

5) Chemical Energy

G. FORCE (F)

That which influences motion. A push or pull expressed in pounds.

H. GRADE (G)

The change in elevation in a specific direction along the centerline of a roadway or the path of a vehicle. Grade is positive (+) if the surface rises in the specified direction and negative (-) if it falls in that direction.

I. GRAVITY (g)

The force that pulls all things to the ground. The acceleration force of gravity is 32.2 feet per second per second (32 fps^2).

J. HEIGHT (h)

A vertical distance measured in inches or feet. The distance from the apex of something upright to the surface the object is resting on.

K. INITIAL VELOCITY (v_i)

A starting rate of motion during any change of position with respect to time. Can be expressed in any value of motion (miles per hour, meters per second, etc.). Expressed in feet per second for this class.

L. KINETIC ENERGY (KE)

Energy possesses by a body based on that object's motion.

M. MASS (m)

The amount of matter in an object. Measured by the object's weight divide by the acceleration of gravity.

N. RADIUS (R)

A line segment from the center of a circle and any point on its circumference.

O. RESULTANT COEFFICIENT OF FRICTION or DRAG FACTOR (f_r)

An adjustment to the coefficient of friction or mu, taking into account the roadway grade, superelevation, and / or the braking efficiency of the vehicle.

A number expressed as a decimal representing the coefficient of friction or mu, plus or minus the grade of the surface times the braking efficiency of the vehicle.

P. SPEED (S)

The rate of progress, usually without regard to direction. Can be expressed in any value of motion (miles per hour, meters per second, etc.). Expressed in miles per hour for this class.

Q. TIME (t)

A measurement, generally in seconds with respect to collisions. The time over which a collision sequence occurs.

R. VELOCITY (v)

The rate of change of distance with respect to time. Can be expressed in any value of motion (miles per hour, meters per second, etc.). Expressed in feet per second for this class.

S. WEIGHT (w)

The product of mass times gravity. Can be expressed in any value of weight (pounds, kilograms, etc.). Expressed in pounds for this class.

II. KEYS

A. In order to properly investigate and report traffic collisions, the investigator must have a clear understanding of the terminology that is accepted around the world in the traffic collision field.

B. Knowledge of the terminology ensures accurate, consistent documentation and reporting.

C. Knowledge of the basis for the variables used in the speed calculation equations enables an officer to use the equations in criminal cases and, if required, testify to them with confidence in court.

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TIRE MARKS AND PHYSICAL EVIDENCE

TOPIC 2.0

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CHARACTERISTICS OF TIRE MARKS

	SKID MARKS					
	LOCKED	IMPENDING	ABS*	YAW	ACCELERATION	FLAT TIRE
'HEEL OTION	Slide, no roll	Retarded, rolling	Retarded rolling	Roll and slip	Slip and spin	Roll, no slip
PERATION	Braking	Braking	Braking	Steering	Accelerating	Rolling
JMBER OF ARKS	Up to 4	Mostly 2, from rear tires	Up to 4	Up to 4	Usually 1, sometimes 2	Only 1, rarely 2
IGHT AND EFT TIRES	Equally strong	Equally strong	Equally strong	Front outside usually stronger	Equal if 2	Usually equal
ONTRAST	Front stronger	Negligible	Front slightly stronger	Rear fainter	Only driven wheels rotating	Equally clear
IDTH	If straight, same as tire	If straight, same as tire	Same as tire	Varies, 1" - 1'	Same as tire	Tire tread edge marks
EGINNING	Usually faint	Faint	Faint	Strong	Strong	Varies
ND	Usually abrupt	Start of locked tire mark	Faint	Strong	Very gradual	Varies
TRIATIONS	Always parallel to the mark	Always parallel to the mark	* Always parallel to the mark	Always oblique	Always parallel to the mark	None
THER ETAILS	Outer edges often stronger on front		Dissipate quickly	Side rib marks may show	Outer edges often stronger	May include rim marks if tire unseated from rim

* When there is steering input by the driver, the tire marks left by a vehicle equipped with ABS are unique insofar as they may be different types of marks. When a vehicle is equipped with ABS, each wheel has a individual sensor This may cause one tire to leave a locked wheel mark while another leaves a yaw mark.

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Tire marks are the most important type of physical evidence left by the vehicles at a traffic collision scene because they tell the complete story of how the collision occurred, and they do not lie.

The collision investigator must properly identify and interpret the tire marks in order to accurately report the scene physical evidence for later analysis by either them (after this class), or a trained collision reconstructionist.

An important part of physical evidence documentation is photography. Different photography techniques must be used in different situations in order for the photographs to properly depict the scene as it was at the time of the investigation.

I. Basic Principles of Physics – In the 1680's, Sir Isaac Newton studied and defined how objects move and interact with one another:

A. Newton's First Law of Motion:

"A body will remain at rest or in uniform motion unless it is acted upon by an unbalanced force"

1. When a vehicle skids, it loses directional stability and slides in a straight line until it comes to a stop. This is an example of directional uniform motion. The vehicle comes to a stop because of the friction between the tires and the roadway (the unbalanced force).

2. Now let's add a collision into the mix. Without a collision, the vehicle described above will slide in a straight line. If another vehicle collides with it while it is skidding (an unbalanced force), its direction will change.

3. These changes in direction in tire marks are very important for collision investigators in that they can be used to establish the Area of Impact

B. Newton's Second Law of Motion

"The acceleration of an object is directly proportional to the applied force and inversely proportional to its mass" or "If the net force acting on a body is not zero, the body will be accelerated in the direction of the force"

This is why in traffic collisions, "size and speed wins".

C. Newton's Third law of Motion

"For every action there is an equal and opposite reaction." or "Whenever one body exerts a force upon a second body, the second body exerts force upon the first."

This concept is used in more advanced accident reconstruction to determine the speeds of the vehicles and is beyond the scope of this class.

II. Tire Mark Definition and Characteristics

A. Tire mark definition:

1. A mark left on any surface by a tire through friction.

2. The term "tire mark" includes all evidence of marking.

B. The three basic methods of leaving visible tire marks:

1. Extreme Deceleration

a. Braking causing the wheels to cease rotation.

b. Damage causing the wheels to cease rotation.

2. Extreme Change of Direction

a. From an intentional effort on the part of the driver

b. From an impact/contact with another object/vehicle

3. Extreme Acceleration

a. Propelling force or thrust generated exceeds the pavements frictional resistance.

b. "Peeling Out": Accelerating at a rate where the rear tires lose traction with the roadway.

C. What tire marks indicate

1. The vehicle's actions

   a. Braking

   b. Accelerating

   c. Turning

2. In some cases, the minimum speed of the vehicle.

3. The vehicle's direction of travel.

4. Location of the vehicle on the roadway surface.

5. Point or area of impact.

6. Possible mechanical failure.

III. Types of Tire Marks

A. Impending: Wheel rotating slower than the forward motion of the vehicle

B. Locked Wheel

1. Non-rotating wheel, moving in a straight or curved line in the original direction travel.

2. If tires in line with the skid, striations will be parallel to the direction of travel.

3. Front vs. Rear characteristics

   a. Front are darker on the outside edges and striations are lighter in color due Overdeflection.

   b. Rear have light outside edges and darker striations due to Underdeflection.

   c. Overdeflection and underdeflection caused by weight shift around the vehicle's pitch axis during heavy braking.

4. Four Wheel Locked Overlapping vs. Four Wheel Locked Independent

   a. Four wheel locked overlapping tire marks occur when the rear tires skid and mark directly over the marks left by the front tires. When calculating speed from four wheel locked, overlapping tire marks, deduct the wheelbase or a standard 10 feet from the total skid length.

   b. Four wheel locked independent tire marks occur when all four skids can be seen independent of one another. No deduction of 10 feet for the wheelbase should be taken when applying the tire marks to a skid chart.

5. Scrub Marks

   a. A locked, braked, or rotating wheel of a vehicle sliding in other than a forward direction.

   b. Usually left after impact, except when known to be caused by centrifugal force.

6. Yaw Marks

   a. Rotating tire mark made from a vehicle turning at a rate greater than the frictional force of the roadway.

   b. Striations are perpendicular to the direction of travel.

   c. The rear tire must track to the outside of the front on the same side of the vehicle.

7. ABS Tire Marks

   a. A mark left by a vehicle equipped with an Anti-lock Braking System.

   b. The marks are generally very light in consistency and hard to see.

   c. The tire motion is kept in the impending mode due to the application-release action of the brakes.

   d. If turning during an ABS application, the resulting tire marks may look like the conventional yaw mark on the outside of the turn, and a conventional locked wheel tire mark on the inside of the turn.

8. Skip Skids

   a. A mark left by a locked tire that loads and unloads on the roadway surface.

   b. This can be due to weight shift, a poor suspension or an uneven roadway.

   c. The gaps in the marks must be less than 5 feet.

9. Gap Skids

   a. A mark left by locked tires where the brakes have been applied, released and then reapplied.

   b. The gaps in the marks must be over 5 feet.

10. Acceleration Marks

   a. A mark left on the roadway surface when the propelling force or thrust generated by the vehicle exceeds the roadway surface's frictional resistance causing the tires to spin.

   b. Can resemble a locked wheel tire mark in that the striations will be parallel to the direction of travel. Differences are:

      1. Weaved in nature.

      2. Start dark and end light and uneven.

      3. May see shards of rubber and roadway removed at the start of the mark.

IV. Other types of marks on the roadway

A. Gouge marks

1. Left by contact between a hard portion of the vehicle and the roadway (undercarriage, wheel, etc.), where roadway material is removed.

2. Occurs at Maximum Engagement where the vehicles can no longer crush, but have momentum that has to be dispelled. Generally the vehicles will be forced downward onto the roadway, causing the gouge marks.

3. Good indicator of the Area of Impact.

B. Scrape Marks

1. Left by contact between a hard portion of the vehicle and the roadway (undercarriage, sheet metal during rollover, etc.), where no roadway material is removed.

2. Can indicate post-impact direction and orientation of the vehicles.

C. Fabric transfer

1. Left when an ejected motorist, pedestrian, bicyclist or motorcyclist slides across the roadway.

2. Friction between the clothing and the roadway will tear fabric from the clothing or leave a colored "haze".

D. Human tissue transfer

1. Also left when an ejected motorist, pedestrian, bicyclist or motorcyclist slides across the roadway.

2. Friction will tear exposed skin from person leaving a transparent deposit of tissue.

3. May or may not have blood with it.

E. Vehicle fluids

1. Spatter, pooling and runoff will indicate post-impact direction of travel, orientation and at rest position.

2. Document path as you would a tire mark.

V. Photographing Tire Marks

A. Procedure of photographing

1. During daylight hours:

a. Take overall photographs of the tire marks in 20-foot increments, unmarked with chalk, as they were when you arrived at the scene. These photographs should follow the path of the tire marks.

b. Mark the starting points of the tire marks with chalk.

c. Mark the tire marks at 10-foot intervals from the point of impact back to the start of the tire mark.

d. Mark the ending points of the tire marks.

e. Mark the post impact tire marks from the point of impact forward to the end of the tire marks.

f. Re-photograph the marks from start to end at 20-foot intervals.

2. During darkness hours:

a. Identify types of lighting available at the scene

1) 35 MM flash unit

a) Short range

b) 10 - 12 feet

2) Separate flash unit

a) Short to long range

b) As far as 150 feet, depending on the unit used

3) Flash light or vehicle head lights

a) Short to medium range

b)Range depends on the amount of light supplied

4) BE AWARE OF THE LIMITS OF YOUR FLASH UNIT

b. Nighttime photographing procedure:

1) Take overall photographs of the tire marks in 10-foot increments, unmarked with chalk, as they were when you arrived at the scene. These photographs should follow the path of the tire marks.

2) Mark the starting points of the tire marks.

3) Mark the tire marks at 10-foot intervals from the point of impact back to the start of the tire mark.

4) Mark the end points of the tire marks.

5) Mark the post impact tire marks from the point of impact forward to the end of the tire marks.

6) Re-Photograph the marks from start to end at 10-foot intervals. Follow through the point of impact to the ending point of the marks.

7) Remember, you want a logical depiction of the tire marks from start to finish in both a unmarked state and then marked for identification

3. Other areas to photograph

a. The at rest positions of the vehicles: These photos should be taken depicting the vehicles in relation to each other or a recognizable landmark.

b. Vehicle damage and identification.

c. Damage to objects

d. Other evidence:

1) Scrapes or gouges in the roadway.

2) Fluid from vehicles or other sources

3) Physical features of the roadway, including any vision obscurement, etc.

VI. KEYS

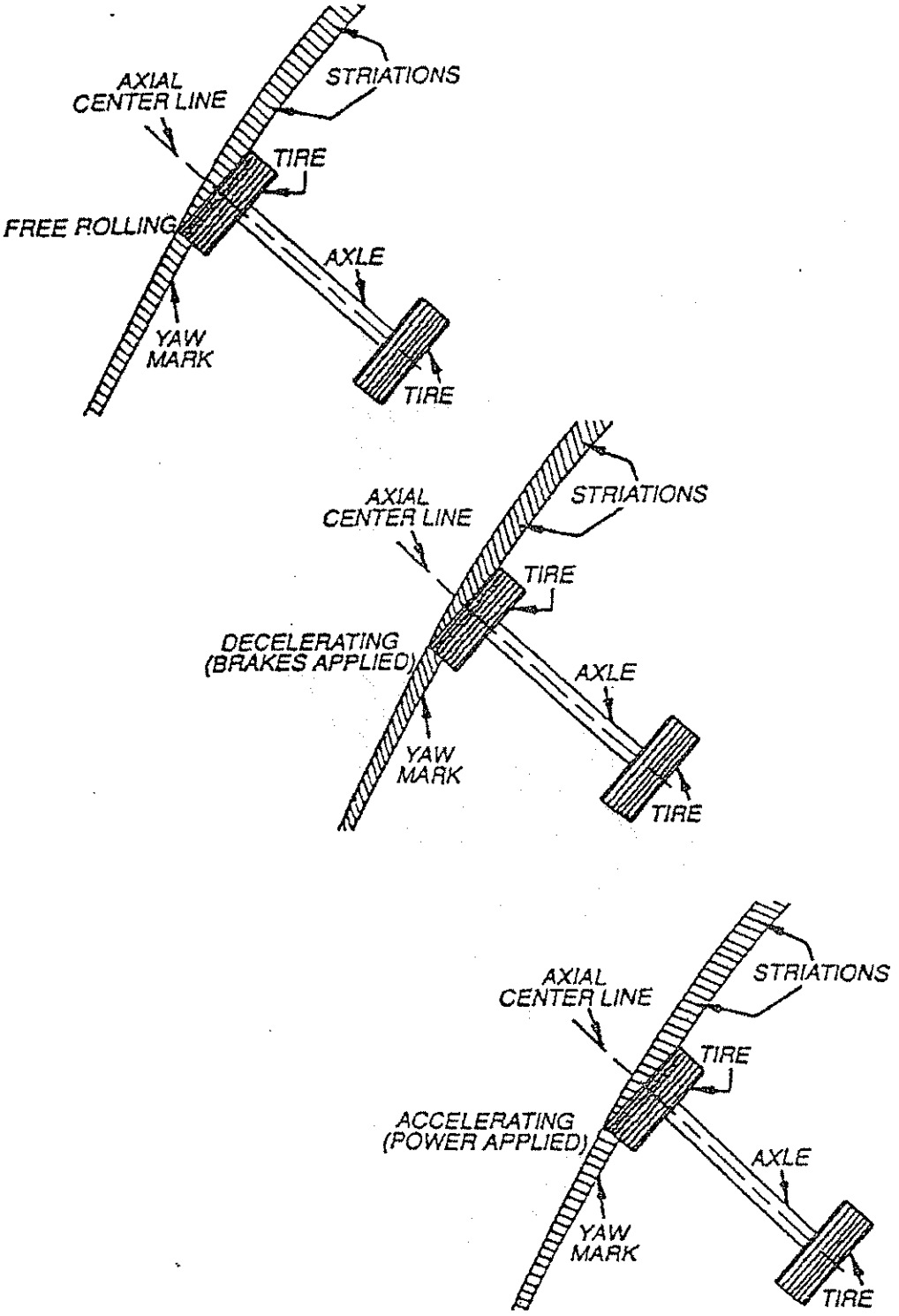
A. Officers assigned to Collision Investigation units cannot be mere report takers. They must be investigators.

B. Knowledge of the characteristics of the physical evidence one may encounter at the scene of a traffic collision is necessary:

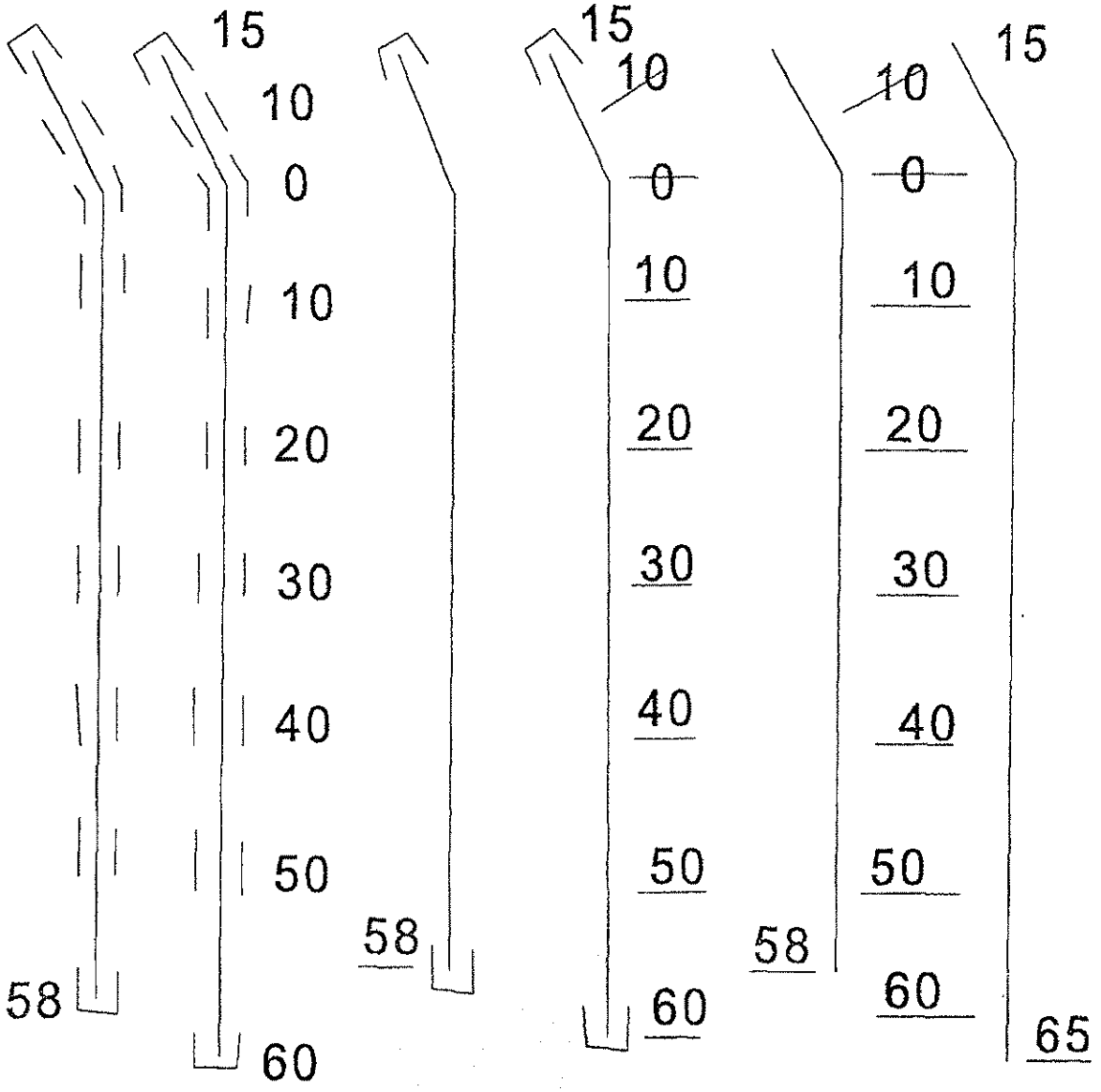
1. To ensure accurate reporting and documentation of the collision.

2. Because the speed calculations that are going to be learned this week are based on proper interpretation of the physical evidence.

3. For court testimony. Once calculations have been completed and are used to establish a violation for which one is to be prosecuted, they may have to be explained to a jury. One of the main points of contention by the defense is usually the interpretation of the physical evidence (type of tire mark) and then its use to calculate the minimum speed of the vehicle.


AXIAL CENTER LINE
STRIATIONS
TIRE
FREE ROLLING
AXLE
YAW MARK
TIRE
AXIAL CENTER LINE
STRIATIONS
TIRE
DECELERATING (BRAKES APPLIED)
AXLE
YAW MARK
TIRE
AXIAL CENTER LINE
STRIATIONS
TIRE
ACCELERATING (POWER APPLIED)
AXLE
YAW MARK
TIRE

MARKING AND PHOTOGRAPHING TIRE MARKS



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TIRE MARK GLOSSARY

ACCELERATION – The propelling force or thrust generated in an amount exceeding the pavement's frictional resistance, made from the drive wheel or wheels of the vehicle.

CENTRIFUGAL SCUFF – See YAW MARK.

CHIP – A short, shallow removal of surface material typically made by a strong, sharp metal object under pressure, usually without striations.

CHOP – A broad, shallow removal of surface material typically made by a strong, broad, sharp metal object under pressure, usually with striations.

CHORD – A straight line connecting two points of an arc or circle.

COEFFICIENT OF FRICTION or MU – A number, expressed as a decimal, representing the resistance of an object sliding on a level surface, divide by the weight of the object.

COLLISION SCRUB – a short, usually broad tire mark made during and after engagement of the vehicles.

CRITICAL SPEED SCUFF – See YAW MARK.

DRAG FACTOR – A number, expressed as a decimal, representing the coefficient of friction, plus or minus the grade of the surface, times the braking efficiency of the vehicle. (Also referred to as the Resultant Coefficient of Friction).

GAP SKID – A braking skid mark that is interrupted by release and re-application of the brakes.

GOUGE – A short to long, shallow to deep, removal of surface material by a hard, sharp pointed object.

GRADE – The change in elevation in a specified direction along the center line of the roadway or the path of a vehicle, expressed in percent.

IMPENDING TIRE MARK – The mark left by a tire whose rotation is slower than the forward motion of the vehicle, usually preceding a locked skid mark.

MIDDLE ORDINATE – A line perpendicular to a chord, connecting the mid-point of the chord to a point on the arc.

NOMOGRAPH – A graph in which three or more scales are arranged where a straight line drawn through the values on any two scales will cross the third scale at a corresponding value; a graphic calculator.

OVERDEFLECTION – A condition in which the pressure of a tire is greater at the outside edges than the middle of the tread; an overloaded, weight shift or underinflated condition.

SCRAPE – An Area of a hard surface covered with broad scratches made by a sliding metal part without great pressure. No surface material is removed.

SCUFF MARK – A friction mark made on a surface y a tire which is both rotating and slipping; acceleration scuffs, critical speed scuffs, flat tire marks.

SCRUB MARK – A locked, braked, or rotating tire of a vehicle sliding in other than a forward direction, except when known to be caused by centrifugal force.

SIDESLIP – See YAW MARK

SKID MARK – A frictional mark on a surface made by a tire that is sliding without rotation. The sliding of the tire may be due to braking, collisions damage or other circumstances.

SPEED SKID CHART – See NOMOGRAPH

SKIP SKID – A braking skid mark interrupted at frequent, regular intervals caused by the loading and unloading of weight on the tires.

STRIATIONS – Narrow parallel streaks or scratches, usually made by friction or abrasion on the roadway or other surface.

SUPERELEVATION – The vertical distance between the heights of the inside and outside edges of a roadway.

TRACK WIDTH – The distance between the center of the tire tread on one side of the vehicle and the center of the tire tread on the opposite side of the vehicle.

WHEELBASE – The distance from the center of the axle of the front wheels to the center of the axle of the rear wheels.

YAW MARK – A mark left on a surface by a rotating tire of a vehicle in a turning movement where the centrifugal force exceeds the frictional force of the surface.

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MATH REVIEW

TOPIC 3.0

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This class is designed to review the concepts of math and basic algebra. The material will include:

- Addition
- Subtraction
- Multiplication
- Division
- Order of operations
- Equation solving
- Powers and radicals'
- The use of calculators

At the end of the class, the successful student will understand and be able to apply the basic concepts of algebra to collision investigation equations with the use of a calculator.

I. Ground Rules

A. There may be several of you that have taken algebra courses in school. This class may be a review and seem simple to you, but may be somewhat harder for others. If you have an algebra background, we may ask you to assist with some of the students that are having problems.

B. Notes on notation

1. Multiplication signs: "x" or "•" or "()"

a. $4 \times 3 = 12$

b. $4 \bullet 3 = 12$

c. $4(3) = 12$; This will be the notation used in this course

2. Division sign: "÷" or "$\frac{x}{y}$" or "$\overline{)\quad}$"

   a. $12 \div 4 = 3$

   b. $4\overline{)12}\,3$

   c. $\frac{12}{4} = 3$; This notation will be used in this course

3. Radical sign: $\sqrt{\quad}$

   a. Used to notate the operation of finding the square root of the number under the radical

   b. This is the number, that when multiplied by itself, equals the number under the radical

   Example: $\sqrt{81} = 9$

4. Exponents: x^2

   a. Used to notate the operation of multiplying the base number by itself

   b. The only exponent used in this course will be the base number squared

   Example: $9^2 = 81$

C. Use of a calculator in this class will definitely be permitted

   1. Do not use the calculator to get ahead of the class

   2. Avoid use of the calculator's "arithmetic logic"

      a. Work out each step

      b. This enables the instructors to find any problems in the mathematical order of operations you may have had

II. There are four basic types of calculators:

A. Basic

1. Handles basic math operations as entered by the user.

2. Does not utilize the Fundamental Order of Operations when completing a series of calculations.

B. Arithmetic Logic

1. Handles basic math operations as entered by the user.

2. Utilizes the Fundamental Order of Operations without user instruction.

a. For algebraic equations to produce the correct answer, the user has to follow a strict order of simplification while working toward the final result.

b. Within each equation, the user must simplify in the following order:

1) Parenthesis

2) Exponents

3) Multiplication

4) Division

5) Addition

6) Subtraction

C. Scientific

Same as the Arithmetic Logic with several additional functions such as:

1. Exponentiation and square roots

a. A single key is set to calculate the exponent function.

b. A single key is set to calculate the square root function.

2. Logarithms

   a. Exponent of the power to which it is necessary to raise a fixed number (the base) to produce the given number.

   b. For example, the logarithm of 100 (base 10) is 2 because 10^2 equals 100.

3. Trigonometric Functions

   a. An area of mathematics involving triangles.

   b. Trigonometric calculations use the relationships between the sides and the angles of triangles to calculate position, distance, speed, and many other things.

   c. A variation on the scientific calculator replaces the scientific functions with statistical functions such as Standard Deviation, 'Sigma' functions, etc.

4. Programmable

   a. Same as Scientific (or Statistical).

   b. Have a limited memory that allows formulae to be entered and recalled.

III. Determining Your Calculator's Functions

A. Enter the following equation exactly as given:

   2 <plus button> 3 <multiplication button> 4 <equal button>

1. If the answer is 20, then you have a Basic Calculator only.

2. If the answer is 14, then you have a calculator with Arithmetic Logic.

3. If you have any other answer, you did something wrong. Go back to the start and try again.

B If your calculator has Arithmetic Logic, you will no longer have to concern yourself with the Fundamental Order of Operations in your calculations.

Example:

50 - 2 + 4 * 3 * 2 =

Solution: (as your calculator "sees" it)

50 - 2 + 24 =

48 + 24 =

Answer: 72

C. You will still have to watch for parentheses.

IV. Basic Mathematical Principles

A. Exponents

1. A small figure placed to the upper-right of a number showing the number of times to multiply that number by itself.

2. This class will only use the square exponent.

   Example: $9^2 = 81$ is the same as writing 9(9) = 81. We multiply the base number (9) by itself, one time.

3. Determining the square of a number (by use of the calculator)

   a. Enter the number you are seeking to find the square of

   b. Push the Square Key [x^2]

      Example: Enter 9; Press [x^2] ; The answer should show 81

   c. Some calculators may have to use the "Inverse" or "2^{nd}" function to calculate the square.

      Example: Enter 9; Press [2^{nd}] or [INV] ; then [$\sqrt{\ }$];

      The answer should show 81

B. Multiplication

1. May be seen as described before, two numbers multiplied together notated by parenthesis

   Example: 4(3) = 12

2. May also be seen in an equation as two variables (symbols) placed next to each other

   Example: $d = \bar{v}t$ Where: d = distance in feet
   v = velocity in feet per second
   t = time in seconds

   To calculate the distance, one has to multiply the velocity factor by the time factor

C. Division

Will be notated as one number "over" another. Always divide the top number, the numerator, by the bottom number, the denominator

Example: $\frac{12}{3} = 4$ Divide the bottom number into the top number

D. Addition - Adding the factors in an equation

E. Subtraction - Subtracting the factors in an equation

F. Square Root

1. The root of a number is another number that, when multiplied by itself, equals the original number.

2. Determining the root of a number (by use of the calculator)

   a. Enter the number you are seeking to find the root of

   b. Push the Square Root Key 

   Example: Enter 81; Press  ; The answer should show 9

c. Some calculators my have to use the "Inverse" or "2nd" function to calculate the square root

Example: Enter 81; Press [2nd] or [INV] ; then [x^2] ;

The answer should show 9

V. The rules of algebra

A. The rules of algebra show us how to rearrange symbols in an equation. Typically, accident reconstruction formulas allow us to calculate a quantity, such as speed in the slide-to-stop equation:

$$S = \sqrt{30\,d\,f}$$

B. In this equation, several symbols appear, with the unknown quantity represented by a symbol that is isolated all by itself on the left side of the equation. All of the known quantities in the equation are either numbers or symbols representing values that have been obtained through measurements, or that have been supplied to us. To solve for the unknown quantity, we simply substitute in the numbers and do the mathematical operations indicated by the formula. For instance, if f = 0.7 and d = 84 feet, we have:

$$S = \sqrt{30\,d\,f}$$
$$S = \sqrt{30\,(84)(0.7)}$$
$$S = \sqrt{1764}$$
$$S = 42\ \text{MPH}$$

C. Unfortunately, when we begin with the underlying physical principles that lead to the reconstruction formulas, the unknown quantity usually isn't isolated on the left-hand side initially. We therefore must use the rules of algebra to move the various symbols around until the unknown symbol is all by itself on the left-hand side.

D. Not many rules are required, but for those who have not used algebra extensively, some practice is required to become proficient at applying those rules. We will express each rule in words, then symbolically, and give a numerical example.

1. **Rule 1. If two quantities are equal, one can be substituted for the other.**

If a = b, and a = x, we can also write b = x

Example: From the definitions class:

$$KE = \frac{1}{2}mv^2 \qquad \text{and} \qquad m = \frac{w}{g}$$

Therefore:

$$KE = \frac{1}{2}\left(\frac{w}{g}v^2\right) \qquad \text{or} \qquad KE = \frac{wv^2}{2g}$$

2. **Rule 2. If a quantity is subtracted from its equal, the result is zero**

If a = b, then a - b = 0

To isolate the unknown:

$$X + 4 = 36$$
$$X + 4 - 4 = 36 - 4$$
$$X = 32$$

3. **Rule 3. If a quantity is divided by its equal, the result is one**

If a = b, then a/b = 1

Example:

$$d = \bar{v}t$$
$$\frac{d}{t} = \frac{\bar{v}t}{t}$$
$$\frac{d}{t} = \bar{v}(1)$$

4. **Rule 4. Adding (or subtracting, multiplying, dividing) the same amount to equal quantities results in two new quantities that are still equal**

$$\text{If } a = b, \text{ then } a + c = b + c$$

Example: If two cars have the same weight (e.g., a = 3200 lbs and b = 3200 lbs), then a = b, and adding the same weight to each (a driver whose weight is given by c = 160 lbs) will produce occupied cars whose weights are the same:

$$a = b$$
$$a + c = b + c$$
$$3200\text{ lb} = 3200\text{ lb}$$
$$3200\text{ lb} + 160\text{ lb} = 3200\text{ lb} + 160\text{ lb}$$
$$3360\text{ lb} = 3360\text{ lb}$$

5. **Rule 5. Adding (or subtracting) 0 to a quantity does not change its value**

$$a + 0 = a \quad \text{and} \quad a - 0 = a$$

6. **Rule 6. Multiplying (or dividing) a quantity by 1 does not change its value**

$$(a)(1) = a \quad \text{and} \quad a/1 = a$$

7. **Rule 7. The order of multiplying (or adding) two numbers is immaterial**

$$ab = ba \quad \text{and} \quad a + b = b + a$$

Example: (3)(7) = 21 and (7)(3) = 21. Likewise, 3 + 7 = 10 and 7 + 3 = 10

8. **Rule 8. The order of equality is immaterial**

$$\text{If } a = b \quad \text{then} \quad b = a$$

Example: If, in an original equation, the unknown quantity is on the right hand side, this rule allows us to place it on the more familiar left hand side

If $ab = x$ and we know that $a = 3$ and $b = 5$, then $(3)(5) = x$, or $x = (3)(5) = 15$

9. **Rule 9. The product of the sum is the sum of the products** (Slide 30)

$$a(b + c) = ab + ac$$

Example: If $a = 3$, $b = 4$, and $c = 5$, we can write:

$$\begin{aligned} a(b+c) &= (3)(4+5) \\ &= (3)(9) \\ &= 27 \end{aligned}$$

But we also have:

$$\begin{aligned} ab+ac &= (3)(4)+(3)(5) \\ &= 12+15 \\ &= 27 \end{aligned}$$

10. **Rule 10. The quotient of a sum is the sum of its quotients**

$$\frac{a+b}{c} = \frac{a}{c} + \frac{b}{c}$$

Example: If a = 4, b = 8, and c = 2, we have:

$$\frac{a+b}{c} = \frac{4+8}{2} = \frac{12}{2} = 6$$

$$\frac{a}{c} + \frac{b}{c} = \frac{4}{2} + \frac{8}{2} = 2 + 4 = 6$$

Note: It is not true that:

$$\frac{a}{b+c} = \frac{a}{b} + \frac{a}{c}$$

E. These various rules can be applied to an equation where the unknown quantity is not all by itself. For example, if, in the equation, a known quantity is added to the unknown quantity, we can subtract the known quantity from both sides

Example: The equation from basic physics that relates the acceleration of an object to it's change in velocity is given by:

$$a = \frac{v_e - v_i}{t}$$

Apply the rules of algebra to this equation to find the final velocity if we know the acceleration, time and initial velocity

Solution: We want to manipulate the equation so that the unknown quantity, v_e, is all by itself on one side of the equation. To do that, we can first get rid of the t in the denominator by multiplying both sides of the equation by the same quantity, t, and using the fact that equals divided by equals produces 1:

$$a = \frac{v_e - v_i}{t}$$

$$at = \frac{v_e - v_i}{t} t$$

$$at = \frac{v_e - v_i}{t} t = (V_e - v_i)(1)$$

$$at = v_e - v_i$$

We now need to get rid of the v_i that is with the v_e. We can do that by adding V_i to both sides of the equation:

$$at = v_e - v_1$$

$$at + v_i = v_e - v_i + v_i$$

$$at + v_i = v_e + 0$$

$$at + v_i = v_e$$

We can now swap the two sides of the equation to get the unknown, v_e all by itself:

$$v_e = at + v_i$$

$$v_e = v_i + at$$

VI. Equation Solving – One Unknown

A. Addition and subtraction are inverse operations

EXAMPLES:

1) $x + 3 = 8$

2) $5 + y = 13$

3) $6 + a = 18$

4) $x - 10 = 2$

5) $y - 3 = 14$

B. Multiplication and division are inverse operations

EXAMPLES:

1) $3x = 12$

2) $4y = 16$

3) $16b = 32$

4) $6x = 30$

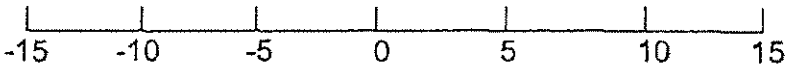
5) $\frac{x}{3} = 12$

6) $\frac{y}{4} = 10$

VII. Negative Numbers

In the equations we will be using there will be negative numbers such as negative acceleration (deceleration).

A. Number Line



B. Multiplication of negative numbers

1. Multiplication of positive numbers will result in a positive answer.

   Example: 5(3) = 15

2. Multiplication of a positive number and a negative number will result in a negative answer.

   Example: 5(-3) = -15

3. Multiplication of a negative number and a positive number will result in a negative answer.

   Example: -6(6) = -36

4. Multiplication of a negative number and a negative number will result in a positive answer.

   Example: -5(-5) = 25

5. (5 + 3)(2) + 6(5 - 8)(3) =

6. 3(x - 26) - 30 =

   Where x = 12

VIII. The Use Of Parenthesis

A. To replace a multiplication sign

Examples: The equation 2 x 4 will be expressed as 2(4)

The equation 2 x "X" will be expressed as 2X

B. To "force" an expression to be considered as a single number or group of numbers exempt from the Fundamental Order of Operations:

Examples:

1) $3(x - 26) - 30 =$

Where $x - 12$

2) $2(a+b)+3a-\frac{b}{2}=$

Where $a = 7$

3) $3(4-2) + 12 =$

IX. Nested Parenthesis

"Nested parenthesis" are often used in complex equations. Always work "from the inside – out" by performing the operations within each basic group first.

EXAMPLE:

$$6(\frac{(8-2)}{3})-10=$$

X. Repeated Multiplying of a Factor

Base, Exponent and Power

A. Base: The number being used as the repeated factor.

B. Exponent: The number which indicates the number of times the base number must be multiplied by itself.

C. Power: The answer obtained.

$$BASE^{EXPONENT} = POWER$$

Example: $5^2 =$
$(5)(5) = 25$

XI. Square Root

The root of a number is notated by the use of a radical sign. The root power is determined by the number to the left and above the root sign.

Examples:

1) $\sqrt{25} = 5$

2) $\sqrt[3]{125} = 5$ This is called the "cube root".

NOTE: When there is no notation to the left and above the square root sign, the number being calculated is automatically the "square root".

3) $\sqrt{25+6} =$

4) $\sqrt{5^2+25(3)} =$

5) $\sqrt{0^2+25(3)} =$

6) $\sqrt{0^2-25(-3)} =$

7) $\sqrt{0^2-(-24.32)(50)} =$

XII. Decimals and Fractions

A. For the calculations of the equations the Los Angeles Police Department is using, there will be no use of fractions. All measurements, or fraction of a foot, will be converted to a whole number and decimal equivalent to the fraction.

Example:

4 ½ feet is the same as

4 feet 6 inches, which is the same as

4.5 feet

B. To convert inches to feet, divide by 12 (the number of inches in 1 foot):

$$9 \text{ inches} = \frac{9}{12} = .75 \text{ feet}$$

C. To convert back to inches, multiply the decimal equivalent by 12. The product will not be exact.

$$.75 \text{ feet}(12 \text{ inches}) = 9 \text{ inches}$$

XIII. Percent Conversions

A. To change a percent value to a decimal value, divide the percent value by 100.

$$35\% = \frac{35}{100} = .35$$

B. To change a decimal value to a percent value, multiply the decimal value by 100.

$$.35 = .35(100) = 35\%$$

XIV. KEYS

A. The basic Order of Operations must be used in order to use the equations you are going to learn in this class. If they are not used, the wrong answer will result.

B. Pay special attention to negative numbers as they play an important part in the resulting answer.

C. Knowledge of algebraic equation manipulation techniques will help to rearrange equations to isolate the unknown.

D. Know your calculator! You may be asked in court to work through an equation in front of a jury

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

PHYSICAL EVIDENCE DOCUMENTATION

TOPIC 4.0

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

The purpose of this class is to familiarize you with the steps needed to properly identify and document tire marks and other evidence

Through lecture and learning activities, you will:

- Locate and identify evidence left on a roadway as a result of a traffic collision.
- Document the evidence using a coordinate method of measurement.
- Write a "Physical Evidence" narrative in the proper format used in the LAPD Traffic Collision Report.

I. Methods of Measuring and Documenting Physical Evidence

A. Tools for measurement

1. Pacing – Estimating a distance by "walking it off". The goal is to take steps that are three feet (one yard) long in order to calculate the distance.
2. This method is very inaccurate because it is difficult to be consistent with each step.
3. Length of pace needs to be checked.
4. Those with shorter legs may have to exaggerate their normal step.
5. Those with longer legs may have to shorten their normal step

B. Rollermeter – A wheeled device that measures distance as it is rolled on a surface.

1. More accurate than pacing over long distances.
2. Still not the most accurate because some distance can be added through the bouncing of the rollermeter on rough surfaces.
3. Must frequently be tested for accuracy.
4. Know the increments of measure:

a. Tenths of feet

b. Inches

C. Tape measures

1. Accurate when used properly.

2. Difficult to use over very long distances.

3. When using as a base line or reference line, ensuring the tape measure is at 90 degrees to the base curb is critical.

4. Different types available:

   a. Steel

   b. Cloth

   c. Increments of inches or feet

D. The four steps of preservation of non-recoverable physical evidence: Identify, measure, record and photograph

1. Identify the evidence

   a. Attempt to identify which tire left the tire mark or which vehicle and part of that vehicle left the gouge or scrape mark.

   b. Identify how each tire mark was left (locked wheel, yaw, post-impact scrub, print, etc.).

   c. Match damage to vehicle undercarriage or suspension to gouge and scrape marks.

2. Measure the evidence

   a. Using an approved method of measurement, locate the position of the evidence on the surface.

   b. Distinguish where changes of direction are located identifying pre and post impact tire marks separately.

   c. ALWAYS record a starting point and an ending point for each piece of evidence. Yes, even if the evidence is only 4 inches long!!

   d. At rest positions of vehicles is important evidence: Measure all four tires for Class I reporting situations.

3. Record the measurements

   a. Keep field notes neat and uniform for ease of transfer to "Physical Evidence" section "f" of your T/C report.

   b. Use reporting format taught in the Basic CI class.

   c. Identify method of measurement used:

      1. Coordinate method: 90 degrees from two curb lines.

      2. Reference line.

      3. Reference points.

4. Photograph the evidence

   a. Photograph the scene as it was when you arrived.

   b. Mark evidence with chalk, lumber crayon, paint.

   c. Re-photograph the evidence.

II. Physical Evidence Documentation Classroom Project

III. Keys

A. Properly identifying and documenting the various types of physical evidence encountered at the scene of a traffic collision is necessary to complete a speed analysis.

B. Using the proper tools and methods of documentation helps produce consistency and confidence in reporting and court testimony.

C. Photography is an integral part of evidence documentation that cannot be overlooked.

IV. Physical Evidence Documentation Field Project

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

DRAG FACTORS

TOPIC 5.0

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

The purpose of this class is to familiarize you with the various factors that influence the slowing of a vehicle.

Through lecture and learning activities, you will:

- Identify the factors that influence the slowing of a vehicle.
- Determine how these factors have influenced the slowing of a vehicle.

I. Definitions

A. ACCELERATION (a)

1. Rate of change of velocity with respect to time.
2. Acceleration may be either a positive value (acceleration), or a negative value (deceleration).
3. The equation used to determine the acceleration rate of a vehicle is:

$$a = fg$$

B. GRAVITY (g)

1. The force that pulls all things to the ground.
2. The acceleration force of gravity is 32.2 fps^2.

C. BRAKING EFFICIENCY (B_e)

1. A given vehicle's ability to retard its forward velocity.
2. The number of wheel groups marking divided by the total number of wheel groups.

D. COEFFICIENT OF FRICTION or MU (f or μ)

A number, expressed as a decimal, representing the resistance of an object sliding on a level surface.

E. GRADE (G)

1. The change in elevation in a specified direction along the centerline of a roadway or the path of a vehicle.

2. Grade is positive (+) if the surface rises in the specified direction and negative (-) if it falls in that direction.

F. DRAG FACTOR or RESULTANT COEFFICIENT OF FRICTION (f_r)

1. A number, expressed as a decimal, representing the coefficient of friction, plus or minus the grade, times the braking efficiency.

2. Expressed as a mathematical equation:

$$f_r = B_e(f \pm G)$$

G. SPEED (S)

1. The rate of progress, usually without regard to direction.

2. Can be expressed in any value of motion (miles per hour, meters per second, etc). Expressed in miles per hour (mph) for this class.

H. VELOCITY (v)

1. The rate of change of distance with respect to time.

2. Can be expressed in any value of motion (miles per hour, meters per second, etc). Expressed in feet per second for this class.

II. Determining the Coefficient of Friction

A. The best method is to conduct test skids.

1. Best scenario is to duplicate the conditions of the collision by:

a. If possible, using the vehicle involved in the collision.

b. Conducting the test skids on the same roadway near the AOI.

c. Conducting the test skids as soon after the collision as possible to duplicate the weather and roadway conditions.

2. Procedure for conducting test skids

a. Completely block off the roadway.

b. Keep safety first in mind.

c. Drive the vehicle at a steady rate. This speed can be documented by using a radar or laser device or the speedometer.

d. After skidding the vehicle to a stop, measure the skid distance. The distance can be documented by using a bumper gun or spotters.

e. When the speed of the vehicle and skid distance have been determined, place the data into the following formula:

$$f = \frac{S^2}{30d}$$

f. The result is the coefficient of friction for the roadway.

g. To ensure an accurate result is obtained, the a minimum of three tests should be completed.

B. Another method that can be used is a drag sled

1. A drag sled uses a section of tire filled with concrete which is pulled along the surface. A scale is used to determine the amount of force needed to pull the sled.

2. Procedures for using a drag sled

   a. Weigh the sled with the same scale used during the pull phase.

   b. Pull the sled across the surface noting the amount of force needed to keep the sled in motion.

   c. Enter this data into the following equation:

$$f = \frac{F}{W}$$

3. Drag sled areas of caution

   a. When the sled is pulled across the surface, the scale must be pulled horizontal to the surface. Any angle in the direction of the pulling force will skew the result.

   b Do not record the highest force needed to pull the sled. The force will be at its highest level just before the sled begins to slide across the surface. This is because it takes more force to break the static resistance of the tire to the surface than it does to keep the sled moving once it has begun to slide.

   c. Once again, conduct multiple tests to ensure an accurate result is applied to the collision evidence.

C. The final method to determine the coefficient of friction of a roadway is to use published tables

1. Refer to the chart contained in the Student Manual.

2. Locate the range of coefficient of frictions for the following examples:

Portland Cement, Traveled, Dry 45 miles per hour:

Answer:

Asphalt, New Sharp, Raining, 25 miles per hour

Answer:

III. Factors Effecting the Coefficient of Friction

A. Roadway surface: Asphalt, concrete, dirt, gravel, etc.

B. Tires

1. Passenger cars use a soft compound to help with the comfort of the ride.

2. Commercial truck tires are made with a much harder compound to help with tire wear and durability.

3. Do not apply the published tables provided in this class to vehicles with commercial grade tires.

C. Grade

1. Upgrade (+) or downgrade (-)

2. Superelevation or banking

3. Roadway crown

D. Weather

E. Other factors that are present, but that are so minute that we do not account for them.

1. Higher Speeds

2. Wind

3. Vehicle weight

4. Tire size

IV. How Braking Efficiency Can Affect the Stopping Ability of a Vehicle

A. Worn Brakes

B. Low brake fluid

C. Brakes out of adjustment

D. Overloaded vehicle

E. Loss of hydraulic or air pressure

F. Brake fade

V. Resultant Coefficient of Friction

A Weight transfer

B. Locked v. Rolling wheel

C Other considerations

1. Pedestrian

2. Down motorcycle – gouging or sliding

3. Sheet metal – rollover

VI. Grade

A. Methods and tools that can be used to determine the roadway grade

1. 100" string, line level and tape measure method

a. Attach the line level to one end of the 100" string.

b. Hold the end of the string opposite the line level on the ground.

c. Pull the string tight and level the string using the line level.

d. Measure 90 degrees from the level string to the roadway surface. This measurement is equal to the percentage of grade of the street .

e. The measurement to the ground is equal to the percent grade of the roadway.

Example:

You measure 12" from the level string to the roadway surface. The grade equals 12 percent. Why?

$$G = \frac{\text{Rise}}{\text{Run}}$$

$$G = \frac{12}{100}$$

G = .12 or 12 percent

2. Tape measures and properly built block wall method

a. Locate a block wall that has been properly built with level joints.

b. Measure a distance of 100" on one of the joints.

c. Take two measurements to the ground, one at each end of the 100" span.

d. Because one end of the 100" span is not at the ground, subtract the smaller of the two measurements from the larger.

e. The result is equal to the grade of the roadway, also in percent because the same equation applies.

3. Blue Blitz template method

a. Draw a vertical line on a notebook or clip board. This line must be 90 degrees to the bottom edge.

b. Drill a small hole in the notebook or clip board near the top of the line.

c. Hang the Blue Blitz temple next to the notebook or clip board by inserting a pen or pencil into the "pivot" hole on the template and the hole in the notebook or clip board.

d. Place the bottom edge of the notebook or clip board on the roadway surface.

e. Allow the Blue Blitz template to swing freely until it is still.

f. Clamp the Blue Blitz template to the notebook or clip board with your hand ensuring that it cannot move.

g. The grade of the roadway can be read where the vertical line on the notebook or clip board crosses the number line at the bottom of the Blue Blitz template

B. The grade should be written as a positive (+) or negative (-) depending on the direction the vehicle was traveling, up or down the grade.

$\mu \text{ or } f = \frac{S^2}{30d}$	Coefficient of Friction (μ or f) Conduct three test skids above or below 30 mph and obtain the average coefficient of friction. If test skids are conducted on the roadway where the collision occurred, the results of this test are the same as the drag factor, even if there is a grade involved.
$B_e = \frac{\text{Wheel Groups Marking}}{\text{Total Wheel Groups}}$	Braking Efficiency (B_e) Evaluate the tire mark patterns to determine the number of wheels that contributed to the slowing of the vehicle.
$f_r = B_e(\mu \pm G)$	Resultant Drag Factor (f_r) Adjust for grade and braking for an acceptable and definable drag factor.
$a = fg$	Acceleration (a) Convert the calculated drag factor to acceleration.
$v_i = \sqrt{v_e^2 - 2ad}$	Initial Velocity (v_e) Calculate the initial velocity based on the acceleration rate of the vehicle, the distance the vehicle slid and the ending velocity of the vehicle on the given surface.

$$f = \frac{S^2}{30d} \qquad B_e = \frac{WGM}{TWG} \qquad f_r = B_e(\mu \pm G) \qquad a = fg \qquad v_i = \sqrt{v_e^{\,2} - 2ad}$$

Work three examples for the first four formulas

Formula #1

$$f = \frac{S^2}{30d}$$

1) The skid test vehicle was traveling 25 miles per hour and skidded for a total of 33 feet.

2) The skid test vehicle was traveling 30 miles per hour and skidded for a total of 36 feet.

3) The skid test vehicle was traveling 35 miles per hour and skidded for a total of 54 feet.

Formula #2

$$B_e = \frac{\text{Wheel Groups Marking}}{\text{Total Wheel Groups}}$$

1) The vehicle leaves four wheel independent tire marks.

2) The vehicle leaves marks from three tires only.

3) The vehicle leaves marks from 1 tire only.

Formula #3

$$f_r = B_e(\mu \pm G)$$

1) A vehicle leaves 4 wheel overlapped tire marks on a roadway with a μ of .73. There is no grade.

2) A vehicle leaves 4 wheel locked independent tire marks on a roadway with a μ of .73. There is a 1% downgrade in the direction of the skid.

3) A vehicle leaves front wheel locked only tire marks on a roadway with a μ of .73. There is a 3% upgrade in the direction of the skid.

Formula #4

$$a=fg$$

1) The vehicle skids on a surface with a coefficient of friction of .75. The acceleration rate is:

2) The vehicle skids on a surface with a coefficient of friction of .73. The acceleration rate is:

3) The vehicle skids on a surface with a coefficient of friction of .55. The acceleration rate is:

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

Scenario:

You arrive at the scene of a traffic collision. The driver of Vehicle 1, traveling northbound, has rear-ended Vehicle 2. Both vehicles have skidded 30 feet into the intersection after the impact. The driver of Vehicle 2 is dead. The driver of Vehicle 1 is drunk. You observe pre-impact four wheel locked independent tire marks left by Vehicle 1 that are 75 feet long. Using a 100" string, you measure a 2" drop in the roadway for northbound traffic.

VII. Keys

A. Out of all of the variables used in a speed analysis, drag factor is contested the most by defense attorneys.

B. The drag factor used in a speed analysis must be established by physical evidence in order to successfully defend it in court.

C. To calculate a justifiable drag factor, an officer must consider:

1. The type of evidence left at the scene.

2. Weather conditions.

3. Vehicle condition and braking efficiency.

4. Roadway grade, superelevation or crown

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

SPEED COMPUTATION

TOPIC 6.0

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

The purpose of this class is to familiarize you with the algebraic equations used in basic speed, time & distance calculations

Through lecture and learning activities, you will:

- Solve speed problems by applying scientifically accepted equations.
- Use the speed solutions to complete time and distance calculations.
- Participate in practical exercises involving the sliding of a vehicle on a surface, documenting and diagramming the physical evidence and completing speed calculations.

I. Equation Sheet

A. The equation sheet is divided into three sections

1. The left section is the variable to be calculated.
2. The center section is a list of the variables that are known.
3. The right section is the equation to be used.

B. This equation sheet can be used during the class and for all tests. Although you will get to know some of the equations by heart, we do not expect you to memorize them.

II. Converting Speed to Velocity (Miles Per Hour to Feet Per Second)

A. Remember: Both of the terms "Speed" and "Velocity" are variables that describe a change of position with respect to time. Any unit of motion can be used to describe the terms (miles per hour, feet per second, etc.)

B. For this class, we will use the term "Speed" to describe motion in units of "Miles Per Hour" (mph) and the term "Velocity" to describe motion in units of "Feet Per Second" (fps)

C. To convert speed (mph) to velocity (fps) use this equation:

$$v = S(1.47)$$

1. The conversion factor of 1.47 is widely used in the accident investigation field. It is derived from the following:

$$1 \text{ fps} = 1 \text{ mph}$$

$$1 \text{ fps} = \frac{1 \text{ mile (in feet)}}{1 \text{ hour (in seconds)}}$$

$$1 \text{ fps} = \frac{5280 \text{ feet}}{3600 \text{ seconds}}$$

$$1 \text{ fps} = 1.47 \text{ (mile per hour)}$$

2. Examples:

10 mph (1.47) =

30 mph (1.47) =

80 mph (1.47) =

100 mph (1.47) =

III. Converting Velocity to Speed (Feet Per Second to Miles Per Hour)

A. To convert velocity (FPS) to speed (MPH), use this equation:

$$S = \frac{V}{1.47}$$

B. Examples:

$$\frac{22.05 \text{ fps}}{1.47} =$$

$$\frac{110.25 \text{ fps}}{1.47} =$$

$$\frac{66.15 \text{ fps}}{1.47} =$$

$$\frac{33 \text{ fps}}{1.47} = 2$$

IV. Minimum Initial Velocity (v_i) On a Single Surface

A. The objective is to determine the minimum initial velocity, or, the velocity at the start of the skid, of a vehicle, where the distance of the skid and acceleration factor are known.

B. The equation used is:

$$v_i = \sqrt{v_e^2 - 2ad}$$

C. The variables in the equation are:

1. v_i – Initial velocity in feet per second
2. v_e – End velocity in feet per second
3. a – acceleration rate in feet per second squared
4. d – distance in feet

V. Minimum Velocity (Multiple Surfaces)

A. When a vehicle slides over two different surfaces, the surfaces must be analyzed separately. This is because each surface has its own coefficient of friction.

B. When using the minimum velocity equation, start calculating from the end of the skid and work backward to the beginning of the skid.

VI. Radius of a curve

A. Up to this point in your training, the radius of a curve equation was only used to calculate the radius of a corner for a scale diagram.

B. Now you will be able to use the equation as part of a process to calculate the speed of a vehicle that leaves a yaw mark during a high speed turn.

C. In order to calculate the speed of a vehicle that has left a yaw mark, you must first obtain the same measurements you would need to complete the Speed / Skid Chart.

1. Chord of any length

Remember: To use the Speed / Skid chart to determine the speed from a yaw mark, the chord has to be 50 feet in length only!

2. Middle ordinate

D. Equation used

$$R = \frac{C^2}{8m} + \frac{m}{2}$$

E. Equation Variables

C – Chord length
m – Middle ordinate length
8 – Mathematical constant
2 – Mathematical constant

F. Once the radius of the yaw nark has been calculated, the minimum speed can be calculated using the following equation:

$$v = \sqrt{Ra}$$

VII. Time & Distance Analyses

A. Time & Distance analyses are valuable in establishing the position of each driver at the time they first observed some stimulus that caused them to slam on the brakes. This stimulus is not necessarily the other vehicle involved in the collision.

B. In many cases, this can also help establish which driver had the best chance to avoid the collision.

C. Also, knowing the position of the drivers at the time they reacted to a stimulus can help in establishing the driver's sight lines.

D. Perception / Reaction Time

1. The time a person takes to perceive a hazard, make a decision what to do, and then carry out that response.

2. Studies have determined that the average perception / reaction time is 1.5 seconds.

3. Perception / reaction time can be effected by numerous factors

a. Age

b. Experience

c. Sobriety

d. Physical Disability

e. Fatigue

f. Level of Attentiveness

E. Perception Time

1. Defined as the general process of detecting some object or situation and comprehending that object or situations significance.

2. For this class, the average perception time we will use is .75 of a second.

G. Reaction Time

1. Defined as the time required from perception to the start of vehicle control.

2. The average reaction time we will use in this class is .75 of a second.

H. Braking Distance

1. The distance the vehicle travels from the time the brakes are applied to the time the vehicle stops or there is a collision.

2. The measured skid distance.

I. Total Stopping Distance

1. The distance traveled during three phases

   a. Perception

   b. Reaction

   c. Braking

2. Used to establish which party had the "final opportunity to avoid" the collision

J. Constant Velocity

1. The rate of motion of an object that has no acceleration.

2. The equation to calculate constant velocity is:

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

3. Used during a time / distance analysis where a constant velocity for the vehicle is assumed to determine the position of a vehicle at the time the driver perceived a hazard. This velocity is the speed calculated for the vehicle at the start of the skids.

VIII. Keys

A. When using calculations to establish the minimum speed of a vehicle, the calculations and results shall be recorded on a 556 Supplemental as a stand alone report.

B. Be careful when deciding your variables. You must be able to justify the numbers you used in the equations in front of a jury.

C. Base all of your variables on physical evidence.

D. **NEVER** add pre-impact skids to post-impact skids to establish the speed of a vehicle.

LOS ANGELES POLICE DEPARTMENT
INTERMEDIATE COLLISION INVESTIGATION

CASE STUDIES