Teaching STEM with Forensics
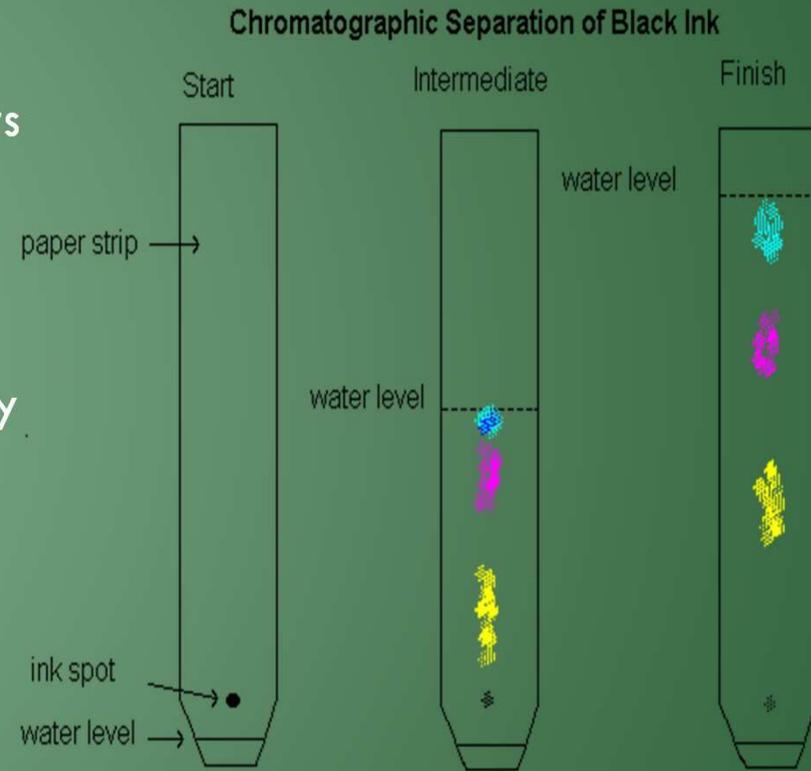
NSTA 2012 WARDS Natural Science

Kathy Mirakovits, Workshop Leader

A Crime Has Occurred

- Read Scenario

- Victim: Tim   Suspect: John

- Evidence/Science to Process
  - Note/Chromatography—Separation Chemistry, Mathematics
  - Broken Glass/Density & Refractive Index—Physics, Mathematics
  - Fingerprint on Glass/Human Individuality—Biology
  - Bloody Shoeprint/Physics, Earth Science
  - Bloodstain Impact Spatter/Physics, Mathematics
  - Skid Marks, Accident/Physics, Mathematics
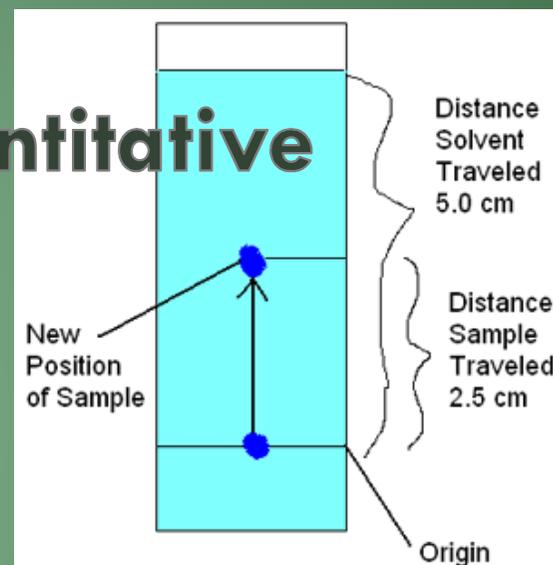
Part A: Chromatography

- Chemistry—Separation Science
  - Use watercolor or permanent markers or pens
  - Watercolor inks—use water as the solvent
  - Permanent inks—use chromatography solvent
  - Black ink is a mixture of colors
  - Dissolve with solvent
  - Colors separate based on chemical properties
  - Not all black pens are the same!
- STEM: Mathematics—Retention Factor

Chromatographic Separation of Black Ink

Start | Intermediate | Finish

paper strip →

water level

water level

ink spot →

water level →

Analysis: Qualitative and Quantitative

Quantitative

Qualitative

Distance Solvent Traveled 5.0 cm

Distance Sample Traveled 2.5 cm

New Position of Sample

Origin

$R_f = \dfrac{\underline{\text{distance traveled by the sample component}}}{\text{distance traveled by the solvent}}$

$Rf = \dfrac{2.5cm}{5.0cm} = \textbf{0.5}$ (no units, they cancel)

R_f and Processing the Evidence

- Today we will do Qualitative Analysis.

- Process your exemplars and crime scene evidence.

- Strips will take ~30 minutes to separate.

You owe $749.00!! This MUST be to me by tomorrow or you are OUT!!!!

*Tim has a Vis A Vis
*John has a Mr. Sketch

Part B: Glass Evidence

- Exemplars of known glass at the scene
  - Pyrex glass
  - Window glass
- Evidence is a piece of glass found in victim's head
- Glass can be analyzed by
  - Physical appearance – size, shape, thickness
  - Color
  - **Refractive Index (RI)**
  - **Density**

Refractive Index

- Refractive Index (RI) a ratio of the velocity of light in a vacuum to it's velocity in a medium

- Equation: $RI = c/v_{medium}$ $c = 3 \times 10^8$ m/s

- As light passes from one medium to a different medium, it changes speed, causing it to bend or refract

The straw appears bent due to refraction of light

Glass ID Using Properties of Refraction

- If two transparent materials have the same RI, light will not refract as it passes from one to the other.

- If solid is placed in liquid with same RI, it will disappear.

- Demonstrations of similar RI
  - Ghost Crystals: cross-linked polyacrylamide
  - Vegetable Oil and Pyrex

Solid is visible in air.

Solid has same RI as liquid. Starts to disappear.

Solid immersed in liquid. Not visible.

Refractive Index Determination of a Small Glass Fragment

- Refractive index of small pieces of glass can be determined using commercially available liquids whose refractive indexes are known
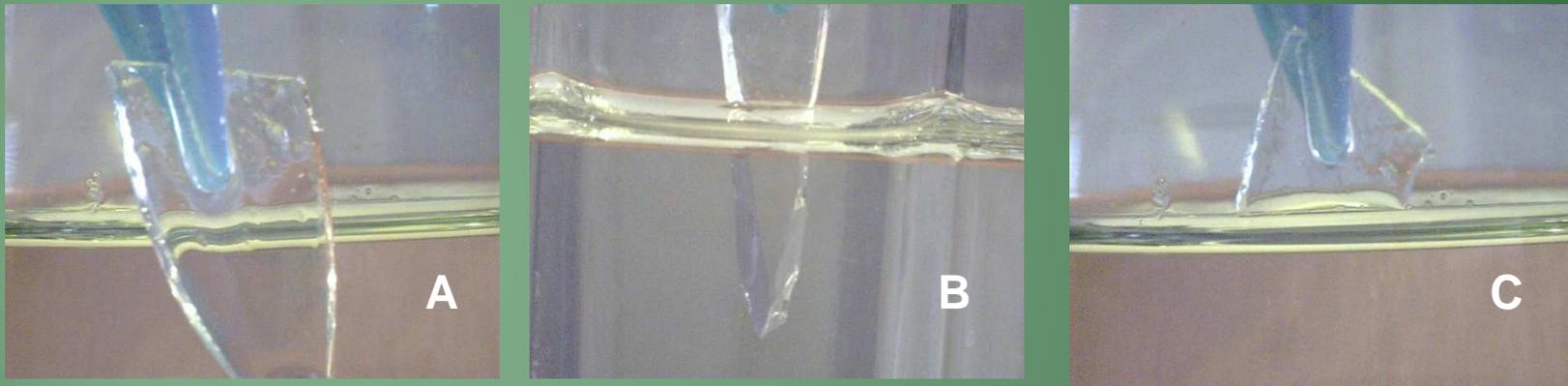

Photo A shows a small piece of Pyrex glass *not immersed* in a liquid.

Photo B shows the same piece of glass *immersed in water*.

Photo C shows the piece *immersed in vegetable oil.*

Pyrex and vegetable oil have similar indices of refraction as shown by the disappearance of the glass in the oil.

Refractive Index Determination of a Small Glass Fragment

Glass Type	RI
Window Glass (soda lime)	1.51
Pyrex	1.47
Tempered Glass (auto)	1.52
Leaded Glass (29%-55%)	1.57-1.67

Liquid Medium	RI
Water	1.33
Vegetable Oil	1.47
Clove Oil	1.53

Measure the RI of Comparison Liquids

- Use plastic dishes filled with liquid to be tested

- Laser light or light box single beam through liquid at a given angle (30^0).

- Trace refracted beam.

- Calculate RI using Snell's Law
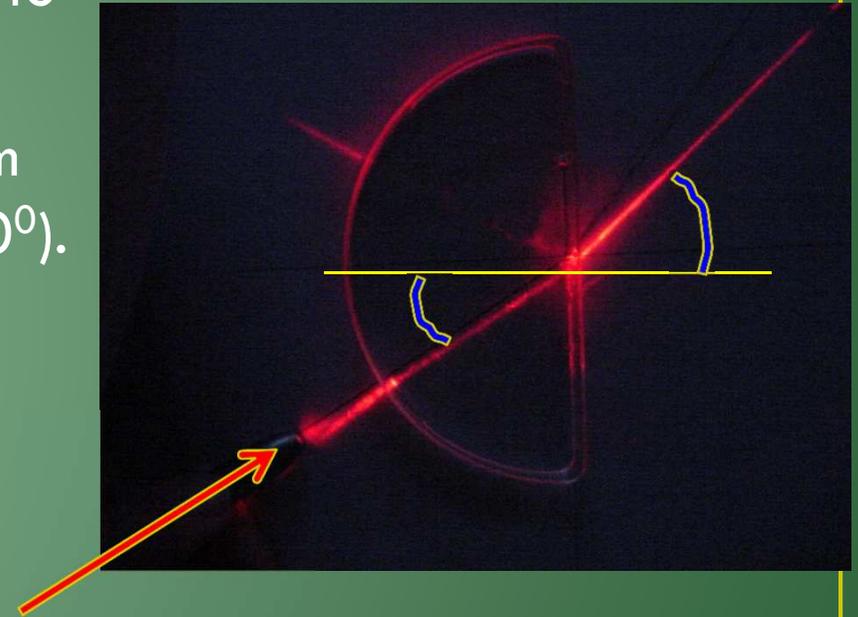
$$n_1 = n_2(\sin \theta_2) / \sin \theta_1 \qquad n_2 = 1.00 \text{ (air)}$$

Measuring The Density
Of A Small Piece of Glass

1. **Mass** the piece of glass.
2. Find *Volume* of glass.
   a. Tare beaker with water.
   b. Tie thread around glass.
   c. <u>SUSPEND</u> the glass in water.
   d. Take mass reading.
   e. Mass of water displaced = Volume of water displaced = *Volume of piece of glass.*
3. Calculate density of the glass.
   density = mass/volume

Window Glass	2.53-2.54 g/ml	(2.5 g/ml)
Pyrex Glass	2.29-2.39 g/ml	(2.2 g/ml)
Leaded Glass	2.65-2.92 g/ml	(2.8 g/ml)
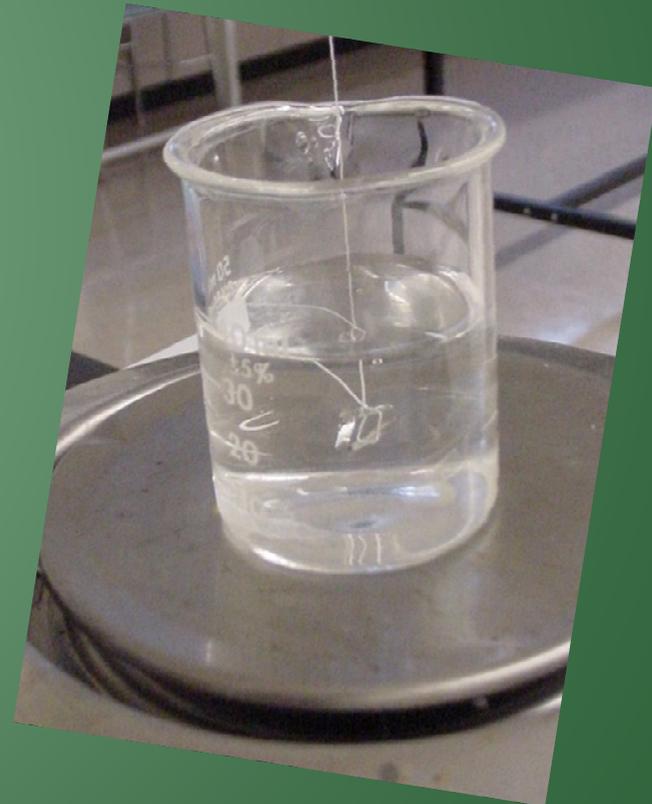
Process the Glass Evidence

1. Each table will process one piece of glass

2. Measure the mass and the volume

3. Calculate the density

4. Share results

5. I will demonstrate how to estimate the RI of the glass.

6. Using 2 liquids of known RI to process the exemplars and evidence

    a) Use water, RI = 1.33

    b) Use vegetable oil, RI = 1.47

Part C: Fingerprint Evidence

- You have exemplar ten print fingerprint cards for John and Tim.
- Watch the procedure to dust and lift a fingerprint.
- Using the magnetic powder and lifting tape, dust and lift the evidence fingerprint from the glass.
- Place your lifted fingerprint on a notecard or your worksheet.
- Using the exemplars, try to identify whose FP this is.

Part D: Shoeprint Evidence

- Shoeprints and Footprints are considered Trace Evidence

- Physics, Biology, Chemistry, Earth Science can be applied

- An identical set of footwear changes as soon as it is worn.

  - Wear pattern (force of body, body mechanics)

  - Additives: glass, gum, rocks, soil, etc.

- Shoeprint Activities:

  - Inking exemplars to compare to evidence

  - Making a cast using Traxtone and BioFoam

Part D: Blood Spatter Evidence

- Blood in flight obeys laws of gravity—a projectile

- Use impact spatter due to blunt force trauma

- Use trigonometry to locate position of source

2000 fps
1/20000 sec
1024 x 896
frame : 0
+00:00:00.000000sec

6Jb3e

Impact spatter from
hammer striking
blood

T L Laber
(Minnesota BCA)

B P Epstein
(Minnesota)
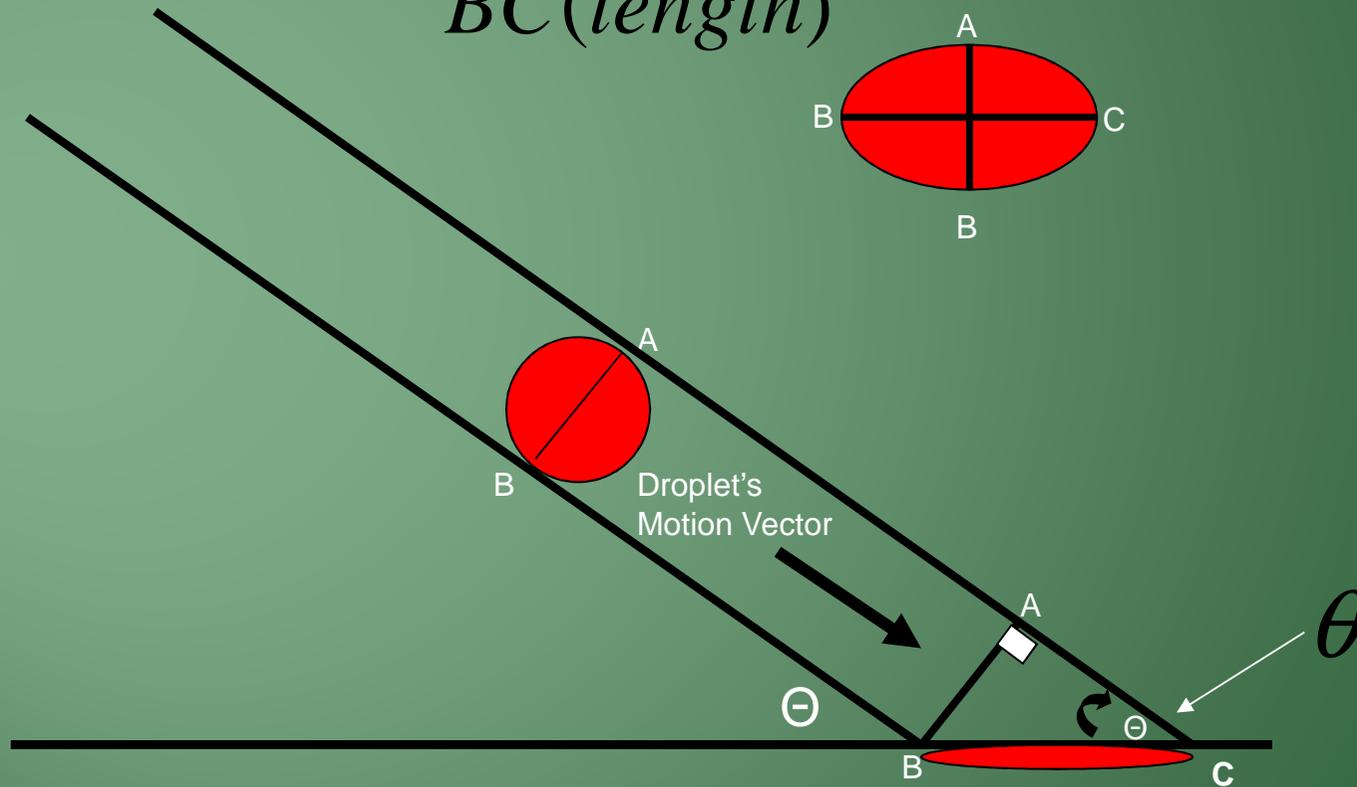
M C Taylor
(ESR, New Zealand)
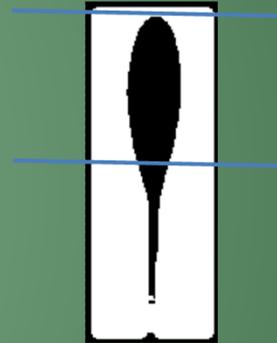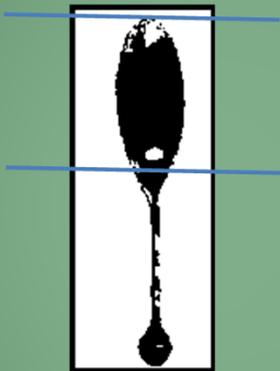
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December 2007

Analyzing the Motion of a Blood Droplet

$$\theta = \sin^{-1}\frac{AB(width)}{BC(length)}$$
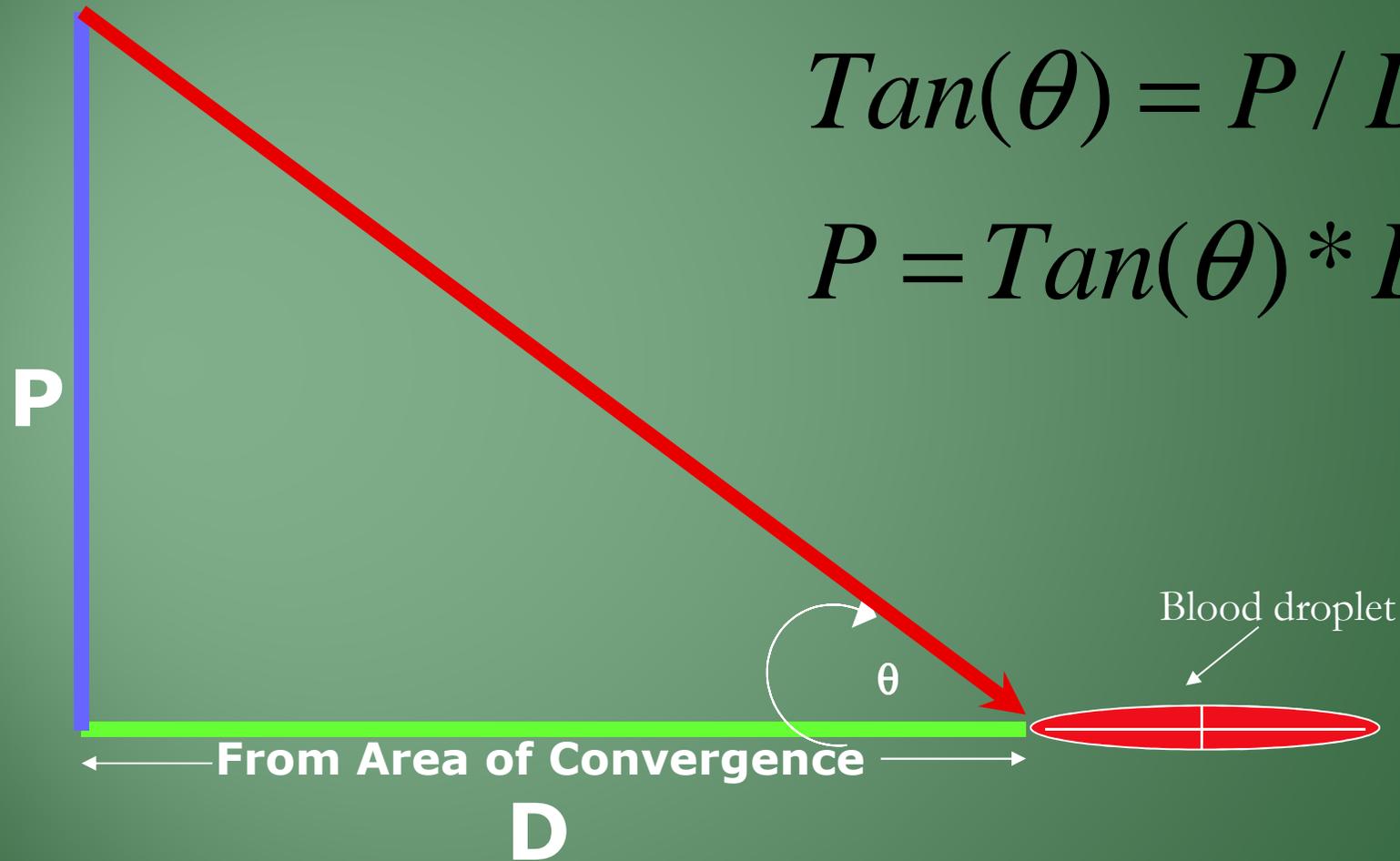

Droplet's Motion Vector

Calculating Impact Angle

- Impact Angle (θ) = $(\sin^{-1})$ width/length
- Practice Sheet.

- Blood Drop A: W/L=0.9cm/2cm 27^0
- Blood Drop B: W/L=1.2cm/1.9cm 39^0
- Blood Drop C: W/L=0.7cm/2cm 20^0

Finding the Third Dimension

$$Tan(\theta) = P/D$$

$$P = Tan(\theta) * D$$

P

θ

Blood droplet

From Area of Convergence

D

Impact Spatter from Blunt Force

- The blood spatter pattern is caused by something hitting a bloodied object and spraying blood in all directions (video)

- Crime scene investigators STRING these stains.

- First find the impact angles of an array of samples

- Tape the string BEHIND the stain

- Use a protractor to angle the string to represent the blood path

- Where multiple strings coalesce is the probable origin of stain

Your Turn: String the Bloodstain

- Blood Drop1
  - W/L = 2/5 = 24^0
- Blood Drop 3
  - W/L = 1/3 = 20^0
- Blood Drop 5
  - W/L = 3/6 = 30^0
- Blood Drop 7
  - W/L = ¼ = 14^0

Accident Investigation-See Handout

- John claims he was going the speed limit of 35 mph, but was distracted due to the conflict with his housemate.

- Use the formula below to find the "drag factor" *f* (coefficient of friction for us physics types) using data from the test skid

$$f = s^2/30d$$ where d is average of the 4 tire distances

- Use the formula below to find John's speed going into the skid

$$s = \sqrt{30\ df}$$

- Was he telling the truth?

Whew! That was a lot of work (FUN!) ☺

- Putting it all together: Use your test evidence to make a conclusion
- Part A: Marker?   Vis A Vis, Tim wrote the financial note
- Part B: Glass?   Pyrex, from baking dish broken at scene
- Part C: Fingerprint   John, right index, proves he had the dish
- Part D: Shoeprint   Matches John's left shoe
- Part E: Bloodstain   Origin is ~2-3" above ground. Self Defense?
- Part F: Accident Investigation   John was 10 mph over, he lied
- FINAL CONCLUSION: John broke a window to get into the house (lost his key again). Reads note from Tim. Tim enters 'cause he's heard the window break. Fight ensues. John hits Tim with Pyrex baking dish and he falls to the floor. John kicks him in the head while he is down. He then leaves quickly. John should be arrested.

WARDS PRODUCTS

- Introduction to Blood Spatter Analysis*   36 V 0047
- Advanced Techniques in Blood Spatter*   36 V 0048
- Chromatography of Inks   36 V 6237
- Forensic Analysis of Glass*   36 V 6240
- Magnetic Fingerprint Kit*   36 V 6139
- Inkless Shoeprint Kit   36 V 6135
- Accident Investigation*   36 V 6268
- THANK YOU!!

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