Examples of Math Applications in Forensic Investigations

Anthony and Patricia Nolan Bertino

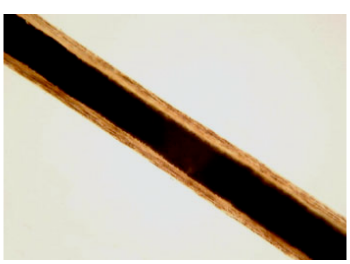
One of the many benefits of teaching forensics to high school students is that they walk through the door eager to learn how to solve crimes. Students find that much of the information investigated in a course in forensics is new information. What many of the students don't realize is that anyone employed in the field of forensics would greatly benefit with a strong background in math, science, technology and writing.

We have found that students in a forensics course are more attentive and more willing to apply math, science and technology if it helps them solve the crime. When a lab report is required in a biology or chemistry class, many students groan. However, if they are writing an expert witness testimony to the jury regarding some type of evidence, the same students seem to be able to write the report with far less difficulty.

A great example of getting students to easily apply math to a crime scene is in their analysis of blood spatter. Students use calipers to measure the length and width of a blood drop. They determine the angle of impact of the blood drop using the law of sine and later calculate the height of the source of blood using the law of tangents.

We would like to provide you with a few examples of how students apply math to their study of forensics.

1. **<u>Hair is it animal or human?</u>**
   Calculate the ratio of the diameter of the medulla (middle, pigmented section of the hair) to the diameter of the entire hair. Animal hair exhibits a ratio of .5 or higher. A ratio less than .5 would be considered to be a human hair.



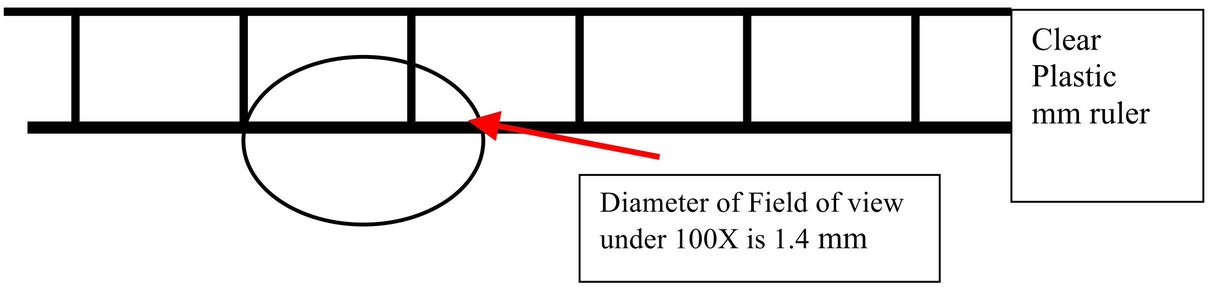
Animal Hair

Human Hair

2. Microscopic Measurement of Pollen

Several different methods can be utilized to measure the size of an individual pollen grain. If your school has a digital microscope, you would be able to take the measurement while viewing the pollen. However, if you do not have a digital microscope, it is still possible to estimate the size each individual pollen grain.

1. Place a clear plastic mm ruler under the 100X field of view. While looking through the ocular lens, estimate the measurement of the diameter of the field of view under 100X. Estimate this measurement to the nearest 1/10 mm. Record your answer. (Most microscopes have a field of view is usually between (1.2) –(1.4) mm



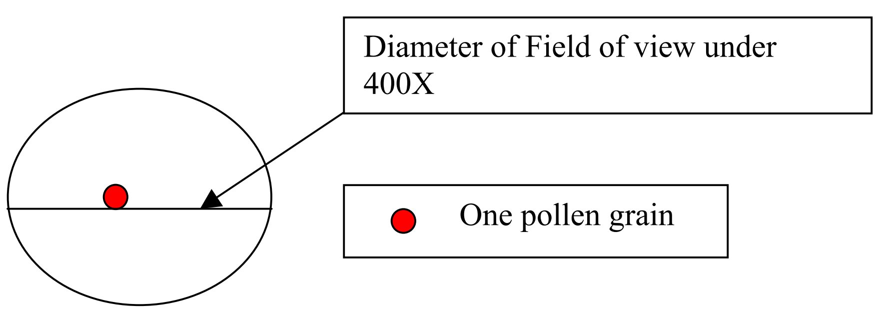
2. To determine the size of the field of view under 400X, take ¼ of the diameter of your field of view under 100X.

$$\frac{\mathbf{100X}}{\mathbf{400X}} = \frac{\textbf{diameter of field of view under 100X}}{\textbf{diameter of field of view under 400X}}$$

¼ (diameter of field of view under 100X) = Diameter of field of view under 400X

¼ of 1.4mm ~ .4 mm diameter under 400X

3. Record your answer to the nearest 1/10 mm.
4. To determine the size of one pollen grain, align one pollen grain along the diameter of the field of view under 400X. **Estimate** how many pollen grains could fit across the diameter of your field of view under 400X.



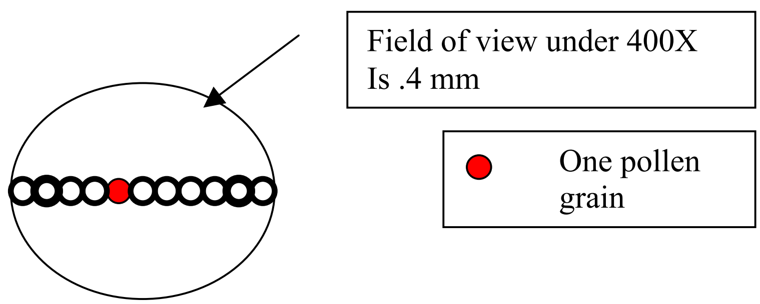
Using the following formula, determine the size of a single pollen grain.

X = size of one pollen grain

(**#** pollen grains that fit) **multiplied by** (size of one pollen grain) = size of 400X FOV
(across 400 X FOV)

For example: if the size of the 100X field of view is 1.4mm

To determine the size of one pollen grain, estimate the number of pollen grains that fit across the diameter of the field of view under 400X while looking through the ocular lens.



Approximately 11 pollen grains fit across the diameter under 400X

If **X** is equal to the size of one pollen grain then:

11 pollen grains = diameter of the 400X field of view

11 X = .4 mm

X = .4 mm/**11**

X = .04 mm (approximately)

3. **<u>Blood Spatter analysis</u>**

a. **<u>Determine impact angles</u>** for each drop of blood by:

i. Measuring the length and width of each droplet of blood

ii. Determining the R value (R= width/length) for each drop

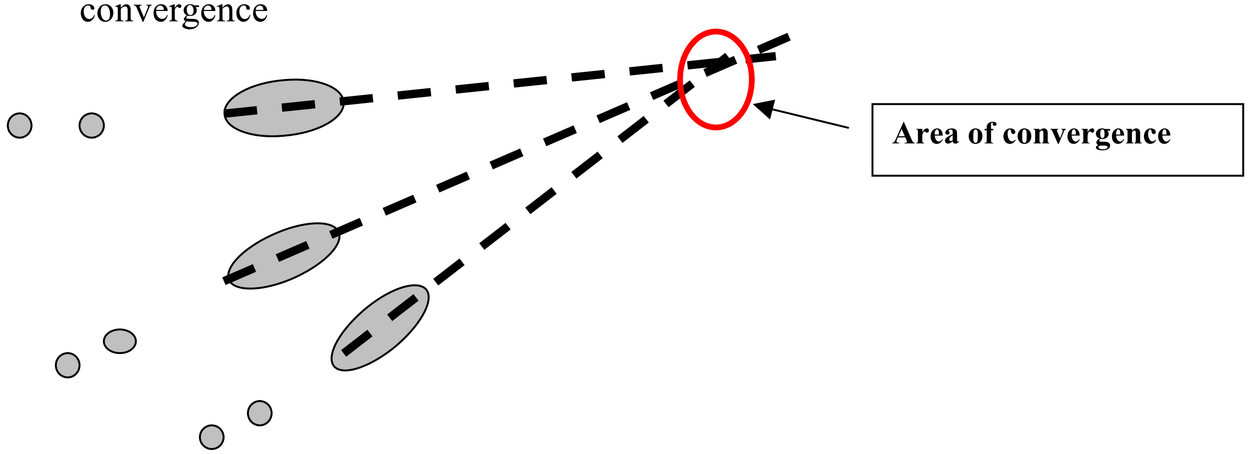
.

R= width/ length of each blood drop

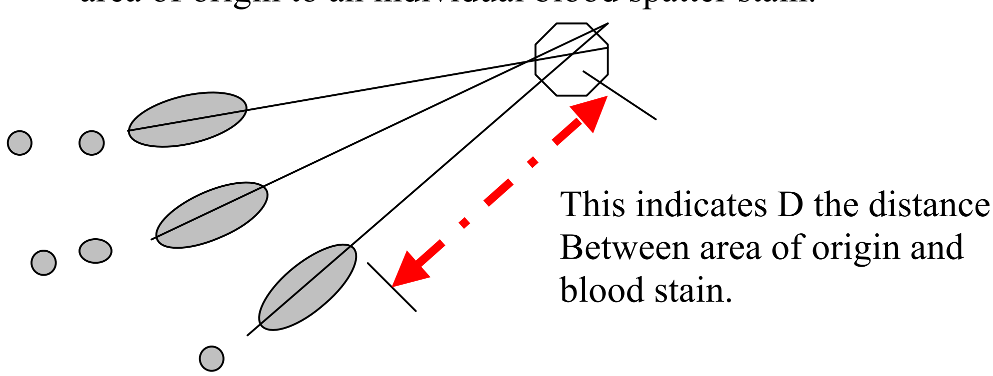
Once you determine the R value, use the sine table or your calculator to determine impact angle

Angle impact= arc sine of width/length

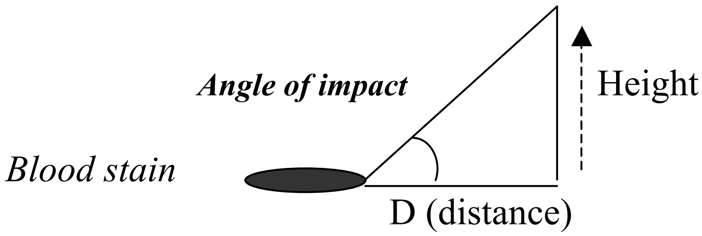
b. **<u>Determine the area of convergence</u>** by drawing lines of convergence



c. Once you have point of origin, **<u>measure the distance</u>** from the area of origin to an individual blood spatter stain.



d. Once you know the distance from the blood spatter stain, and the angle of impact, use the law of tangents to determine the **height of the target** (the source of blood)

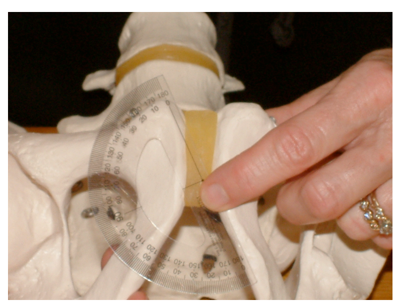


Tangent Angle = $\frac{\text{opposite}}{\text{Adjacent}} = \frac{\text{Height}}{\text{Distance}}$

Tangent Angle = Height/ distance   solve for height
Height =Tangent angle/distance

4. **Bones**

a. Male or Female Pelvis?
Measure sub pubic angle with protractor



Sub Pubic Angle

Male

Female

b. **<u>Race measure nasal index</u>**
Use calipers measure width/length of nasal opening.

Causasian   Mongoloid

c. **<u>Calculate the height of a person based on the size of one bone</u>**

Given a bone, it is possible to estimate the height of the person by Referring to reference tables that provide formulas for the determination of height from a bone.

<u>5. Time of Death Estimation</u>

Using Rigor, Livor and Algor Mortis, it is possible to estimate time of death

Ex. Rigor mortis
starts within 2 hours of death
Rigor is peak at 12 hours
Most rigor fades by 36 hours
Affected by ambient conditions

Ex. Livor Mortis
starts within 2 hours of death
Between 2-8 continues to develop
Coloration permanent after 8 hours

Ex. Algor mortis

Body temperature drops at a rate of 1.4 degrees F/hour for the first 12 hours.

After 12 hours, the rate of heat loss is calculated at .7 degrees F/ hour.

Altered by different ambient conditions

6. Insects and time of death

Estimates of time of death can be made by the presence of different insects found on the body. Many insects undergo developmental stages of egg, larva stages, pupa and adult. Blowflies are usually the first insects to arrive in a series of insects. Since they lay their eggs on warm bodies, their arrival indicate the estimated time of death.

What is frequently used to determine time of death involving forensic entomology is a method known as **ADH**, or Accumulated degree hours. ADH is the amount of thermal energy (heat) required for an insect to progress from one developmental stage to the next in its life cycle. To calculate the ADH, multiply the ambient temperature by the number of hours at that temperature.

To obtain data for a specific insect, experiments are conducted under a constant temperature. The number of hours it took for an insect to progress from one stage to another was recorded. The ADH required for completion of one stage was calculated by multiplying the temperature times the number of hours it took to reach the next stage.

The following Information for Green Bottle Fly raised at a constant temperature of 70 degree F was obtained from the National Library of Medicine at NIH.

ADH of the Green Bottle Fly

From	To	Temperature (Degrees F)	Hours	ADH (Accumulated degree hour)
Egg	First instar	70	23	70 X 23= 1610 ADH
First Instar	Second instar	70	27	70 X 27 =1890 ADH
Second instar	Third instar	70	22	70 X 22=1540 ADH
Third instar	Pupae	70	130	70 X 130=9100 ADH
Pupae	Adult	70	143	70 X 143= 10010 ADH
			Total hours	= 24,150 ADH

When a body is discovered, insects are collected and identified. Using the temperature records and the ADH, it can be determined when eggs were laid and thus determine the time of death.

7. **<u>Chromatography</u>**

Chromatography a method used to separate a mixture of liquids or gases. It can be used in the analysis of ink, paints, chemicals. Ink is spotted on a piece of filter paper and then placed in a solvent. As the solvent moves up the paper and dissolves the mixture of colors, a chromatogram is formed showing a variety of colors. Students can perform a simple chromatography experiment that separates black ink into a variety of colors. An unknown substance can be identified with a known substance if its chromatogram and R_f values are the same

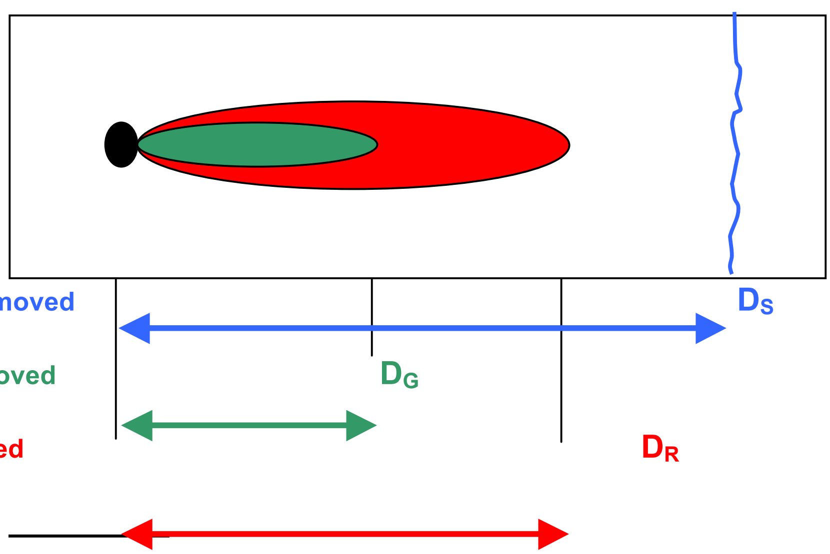
Calculating R_f

$$R_f = \frac{\text{distance (mm) a component color in ink moves from origin*}}{\text{distance (mm) the liquid (front) has moved from the origin*}}$$

*** the origin is the original location of the ink spot before being placed in the chromatographic solution (measure from the pencil line to the edge of the liquid. See example below.**

Measure all distances in millimeters. All R_f distances are a decimal less than one.

Black spot of unknown ●



D_S Distance solvent has moved

D_G Distance green has moved

D_R Distance red has moved

Rf Green = $\frac{D_G}{D_S}$ = ____________

Rf Red = $\frac{D_R}{D_S}$ = ____________