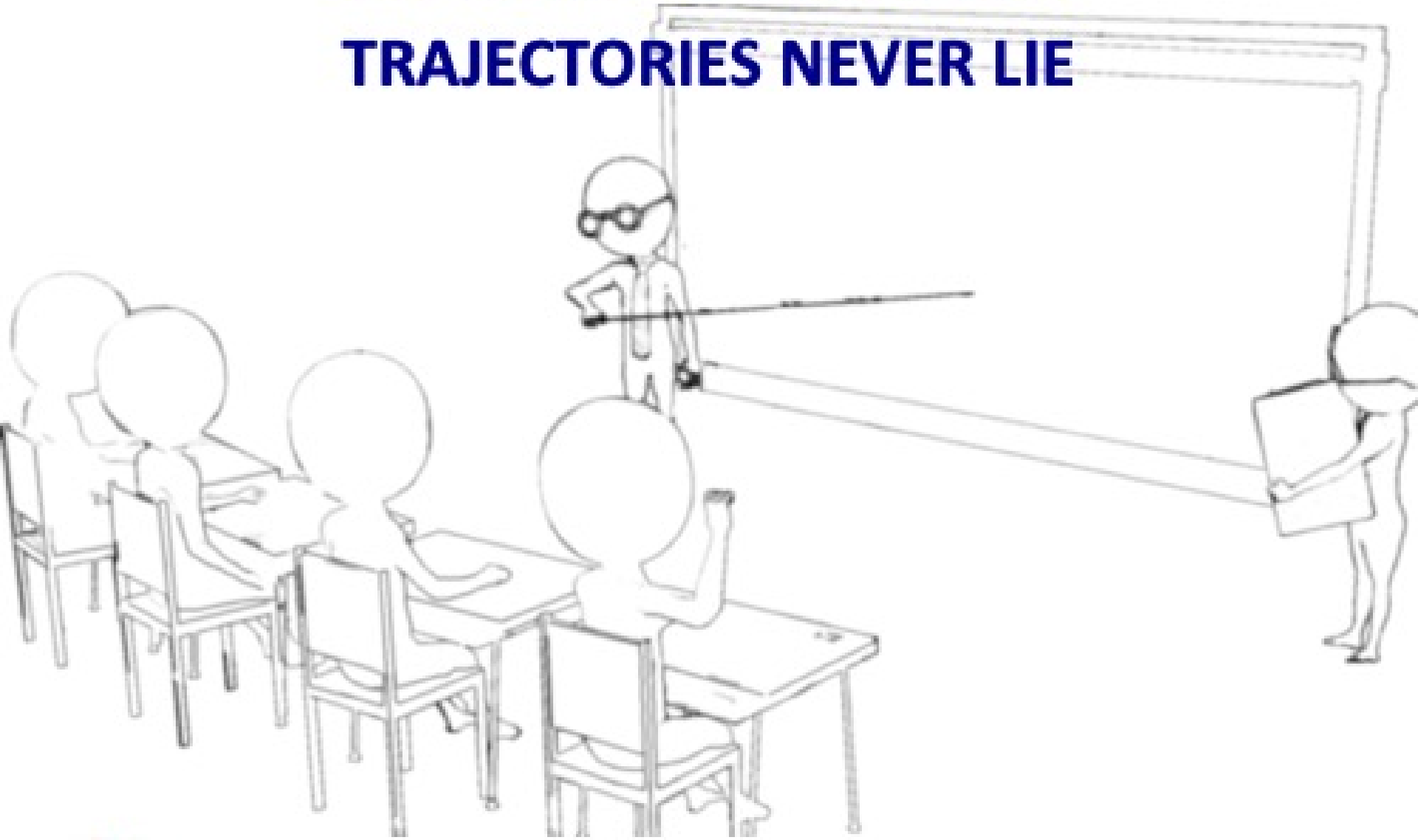
ACSR 2019 CONFERENCE

TRAJECTORIES NEVER LIE



GRAFF Investigative & Forensic Training

TRAJECTORIES NEVER LIE
overview

- The math behind analysis.
  - Evaluating the data: placing the shooter & victim
- Trajectories from ricochets.
- Ricochet angles in sheet metal
- Elevation and Azimuth angle protocol.
- Practical Exercises

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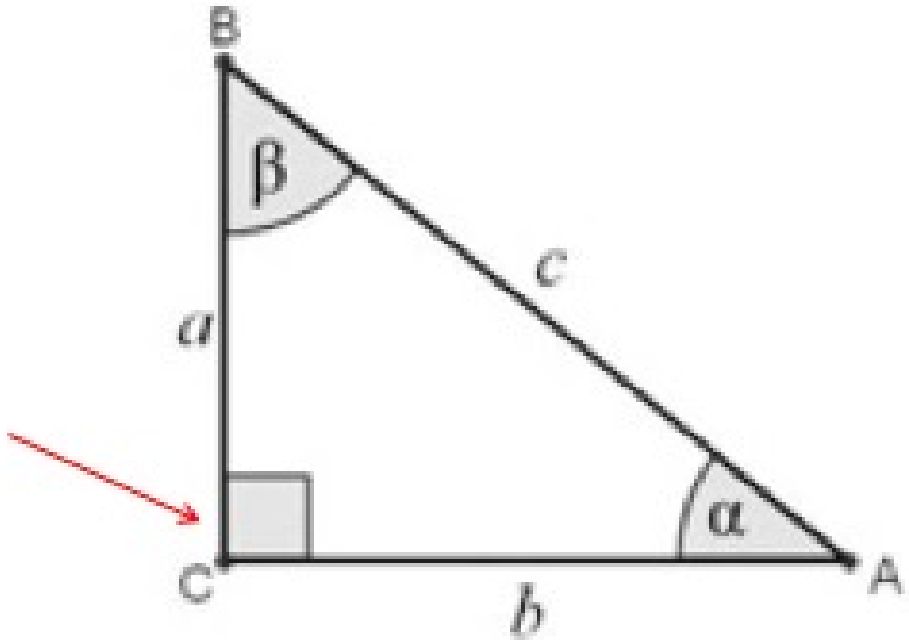
Application of Trigonometry to Trajectory Analysis

A triangles has six components.

A right triangles has one 90 degree angle.

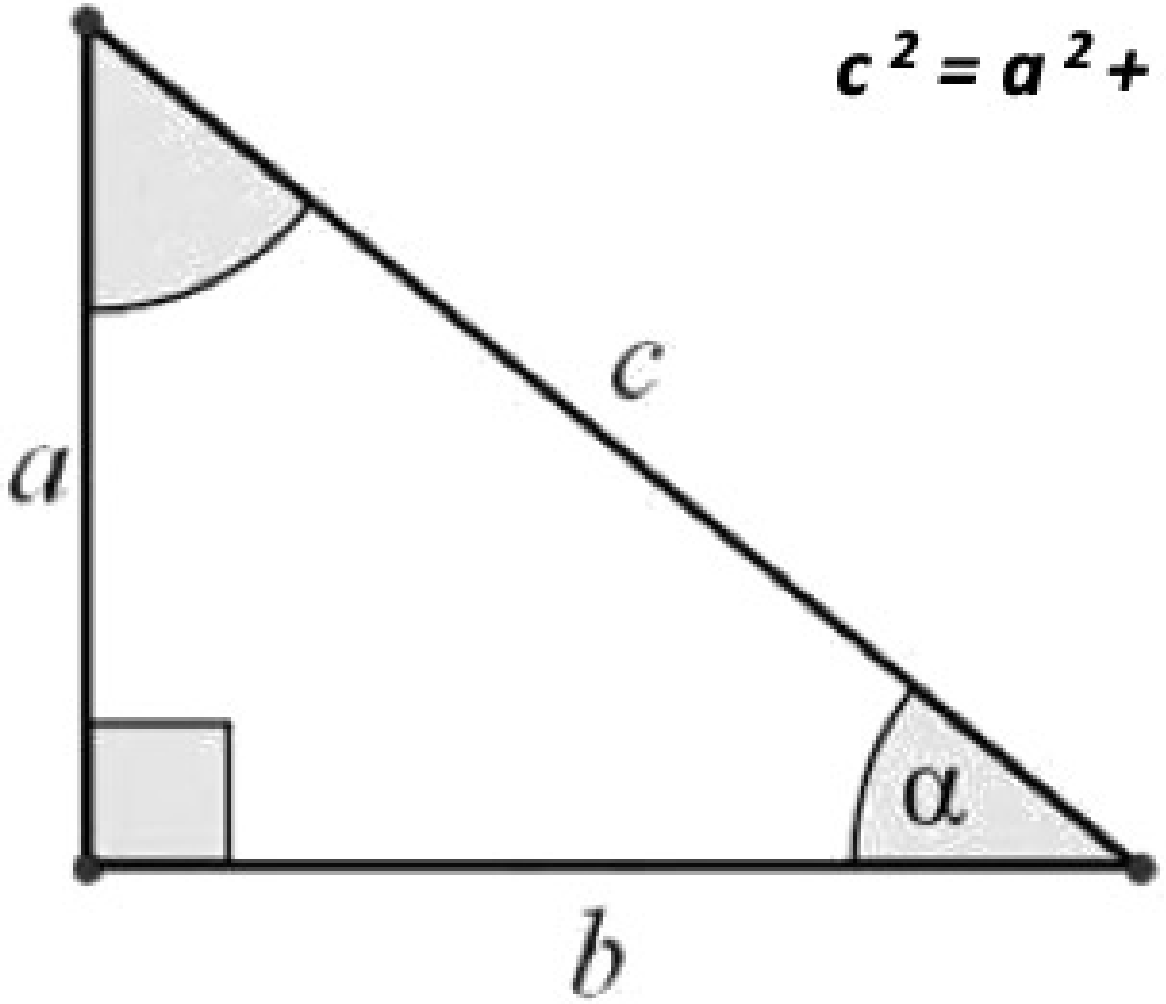
If any 2 other components of the triangle are known, the other 3 components can be calculated.

90 degree angle



If two sides are known, the third side can be calculated:

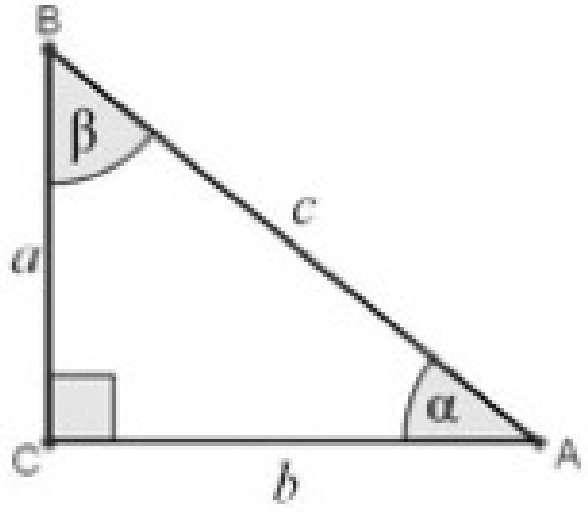
$$c^2 = a^2 + b^2$$

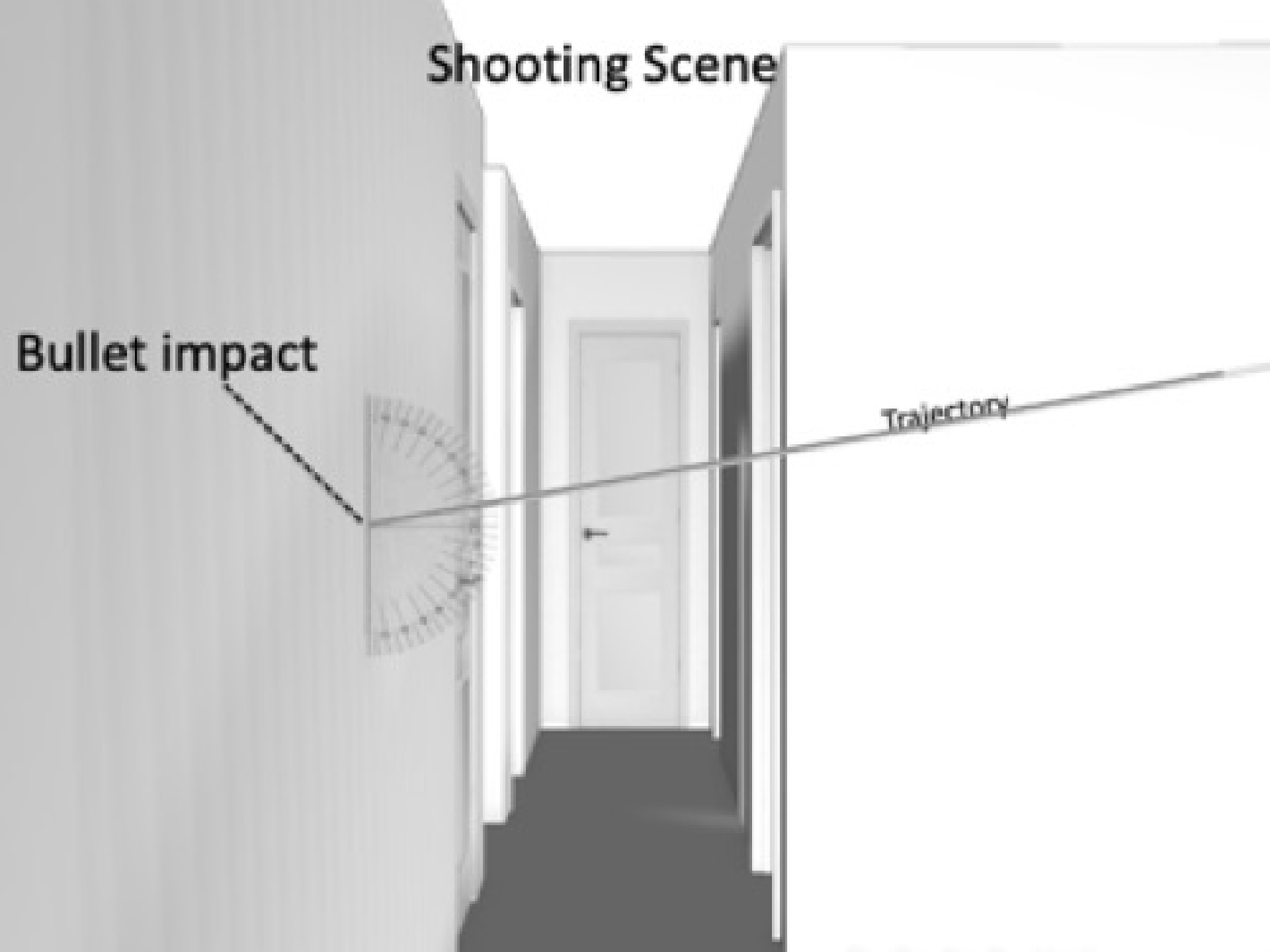


This is known as Pythagorean Theorem

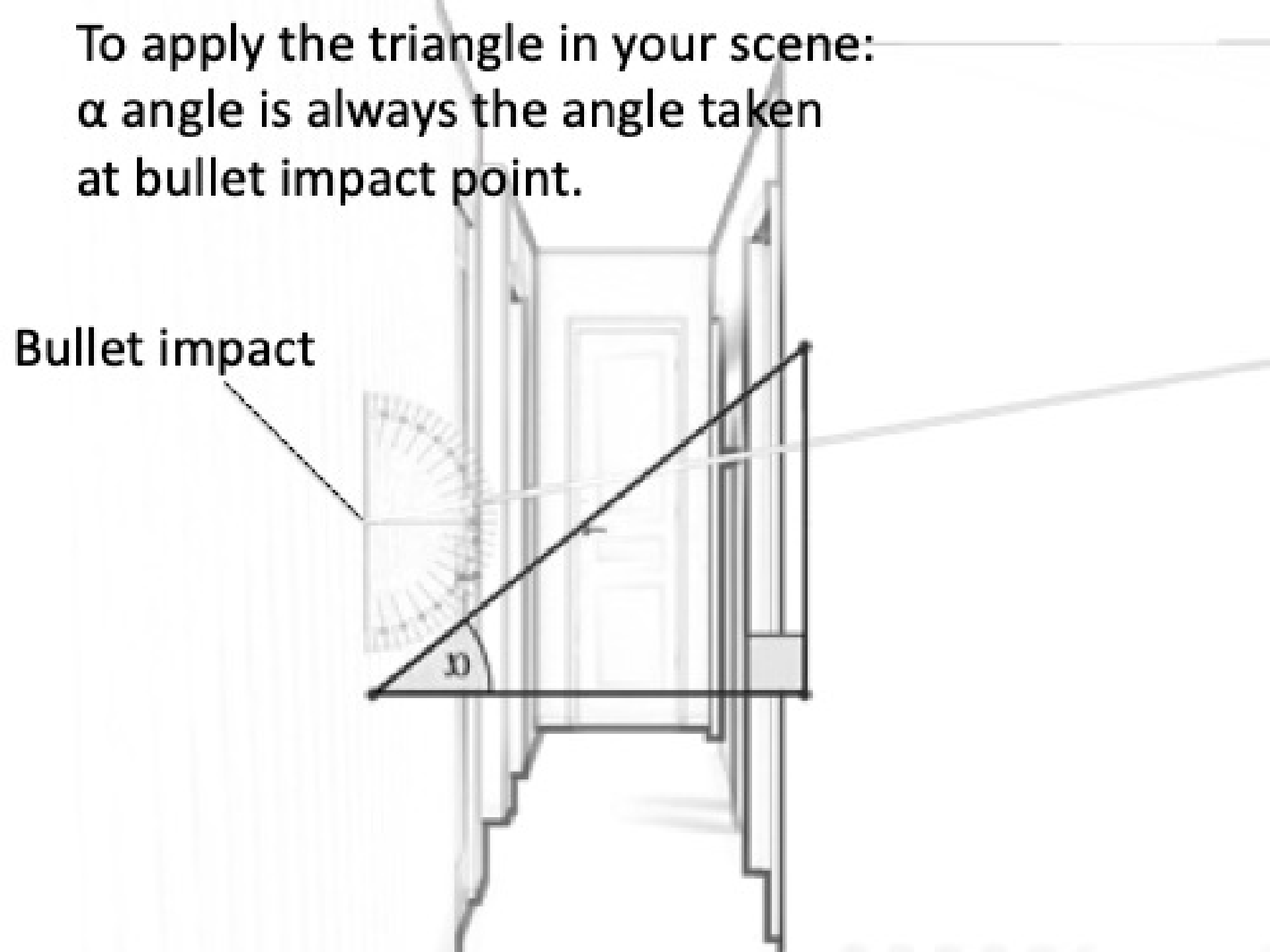
Application of Trigonometry to Trajectory Analysis

- Key to success: Applying right triangle to the scene.

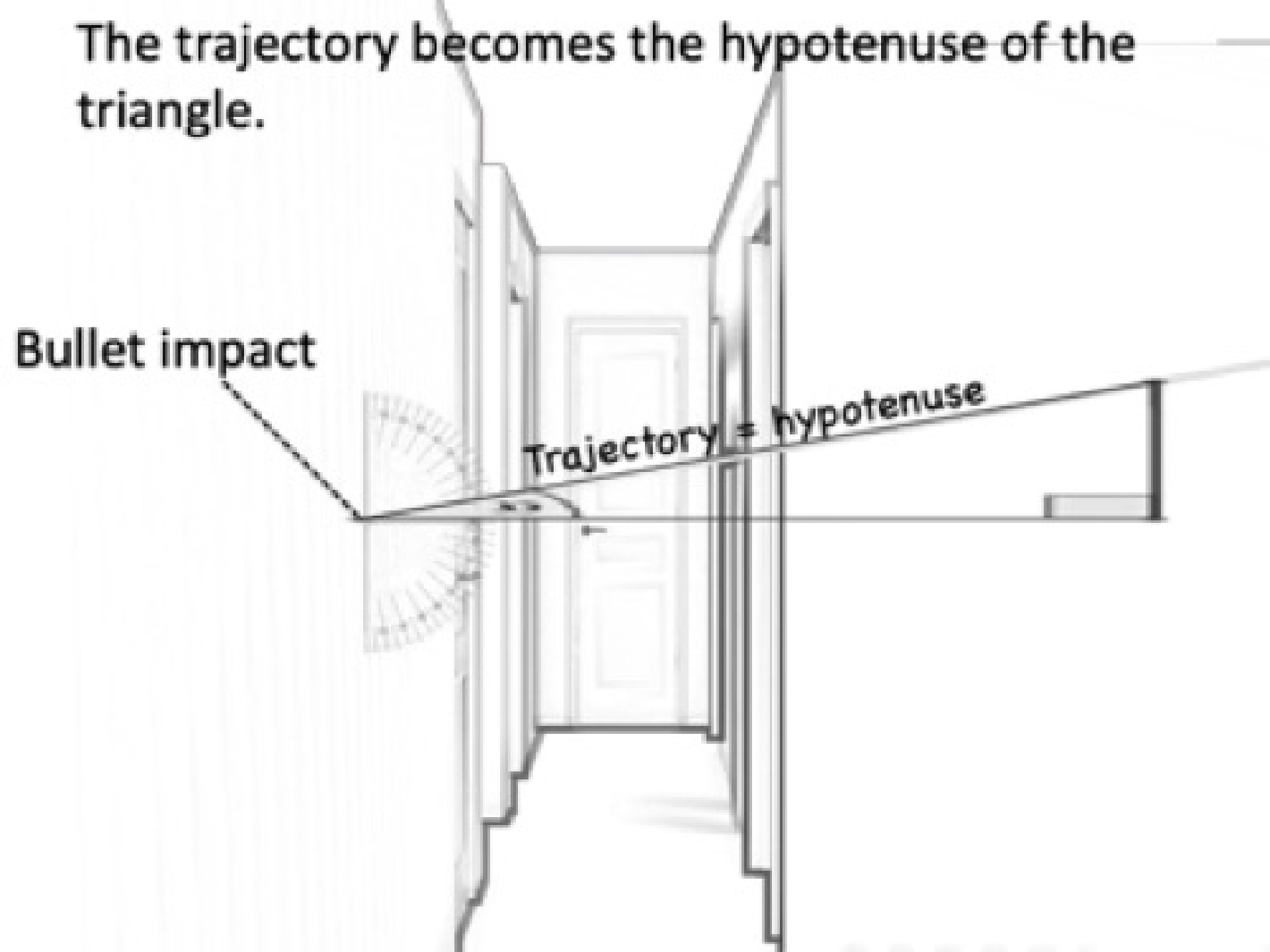



Shooting Scene
Bullet impact
Trajectory

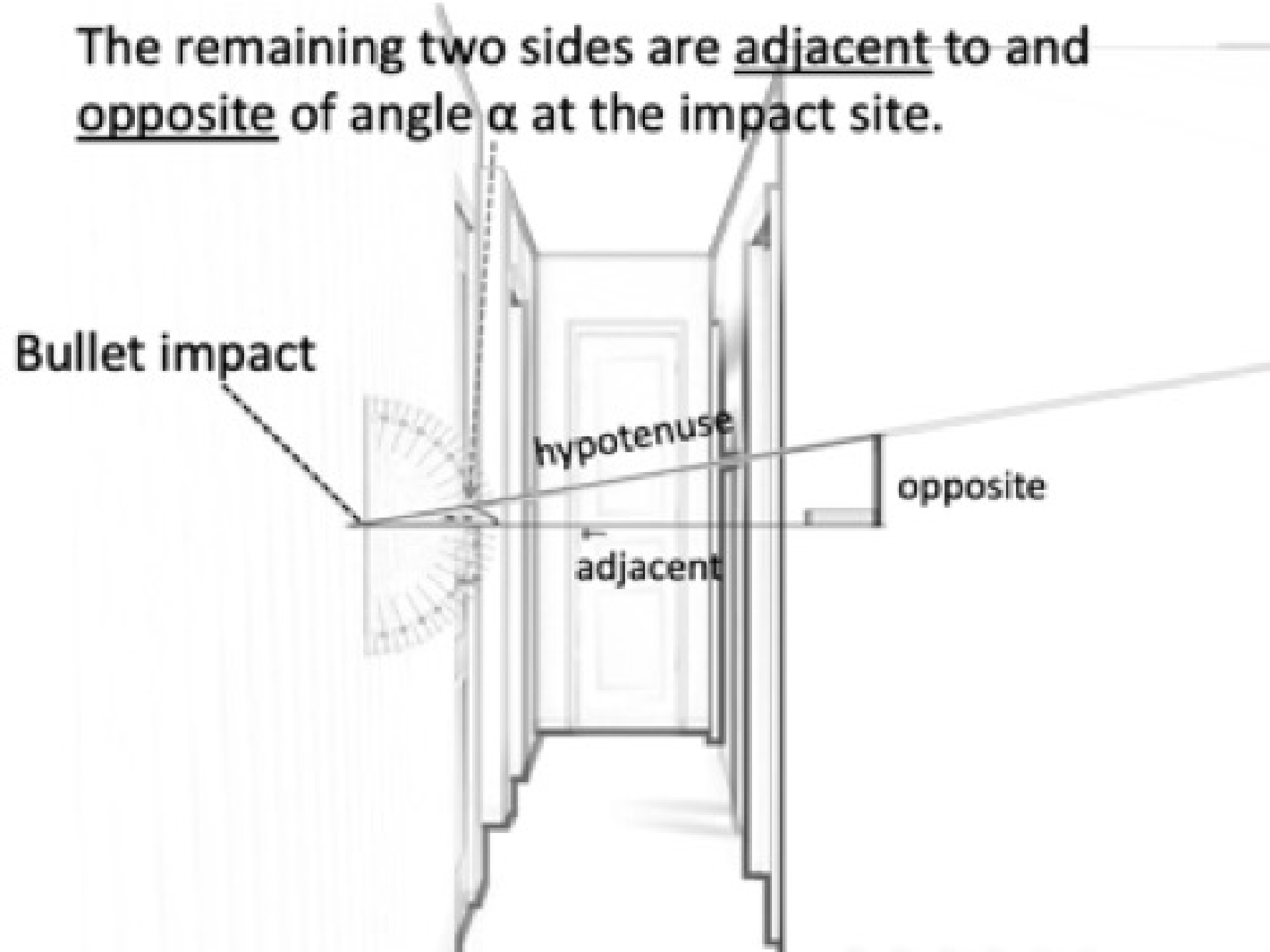
To apply the triangle in your scene:
α angle is always the angle taken
at bullet impact point.



The trajectory becomes the hypotenuse of the triangle.



The remaining two sides are adjacent to and opposite of angle α at the impact site.



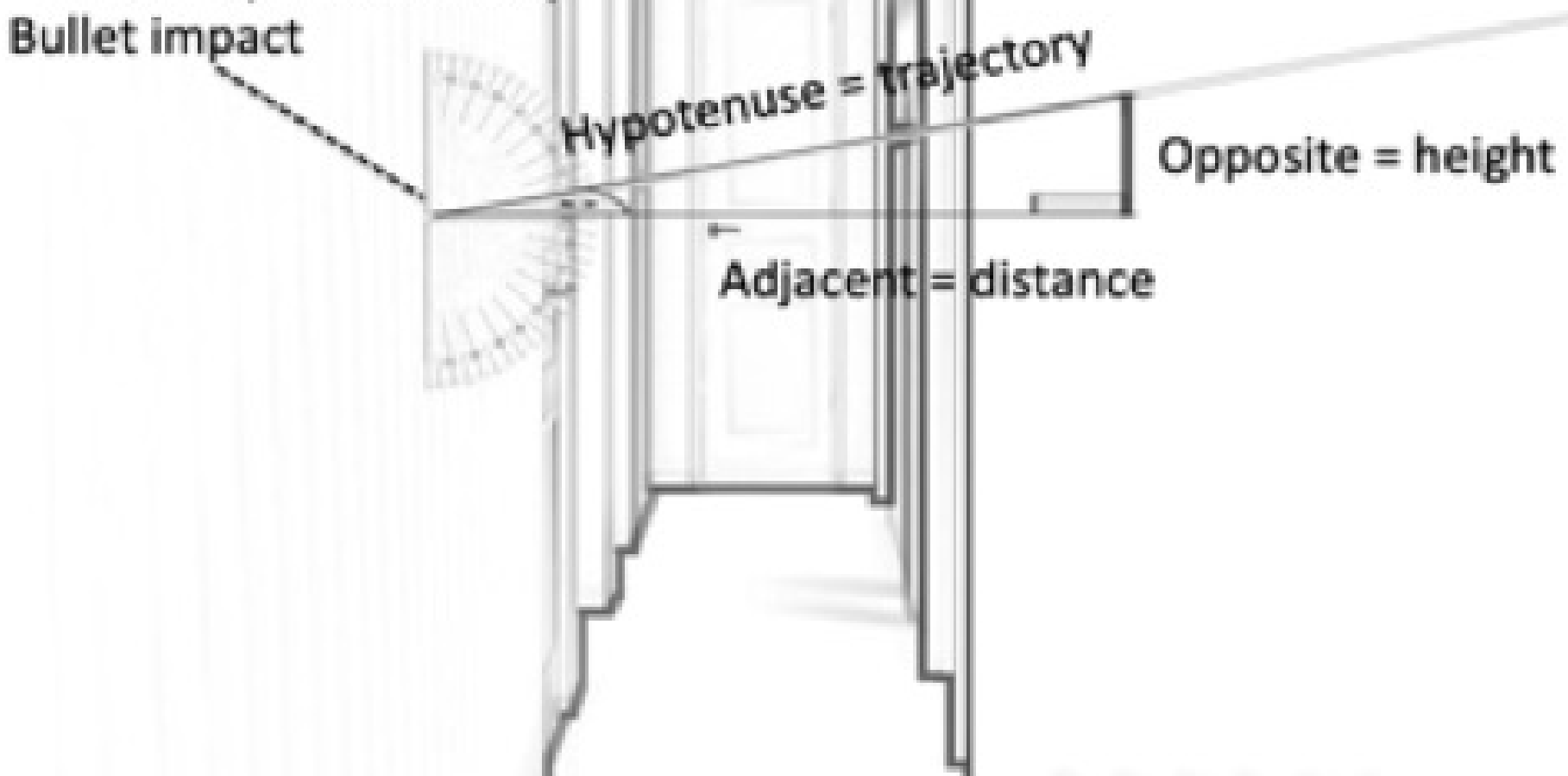
In shooting scenes, parts of the triangle often relate to the event as follows:

α is *elevation or azimuth angle*

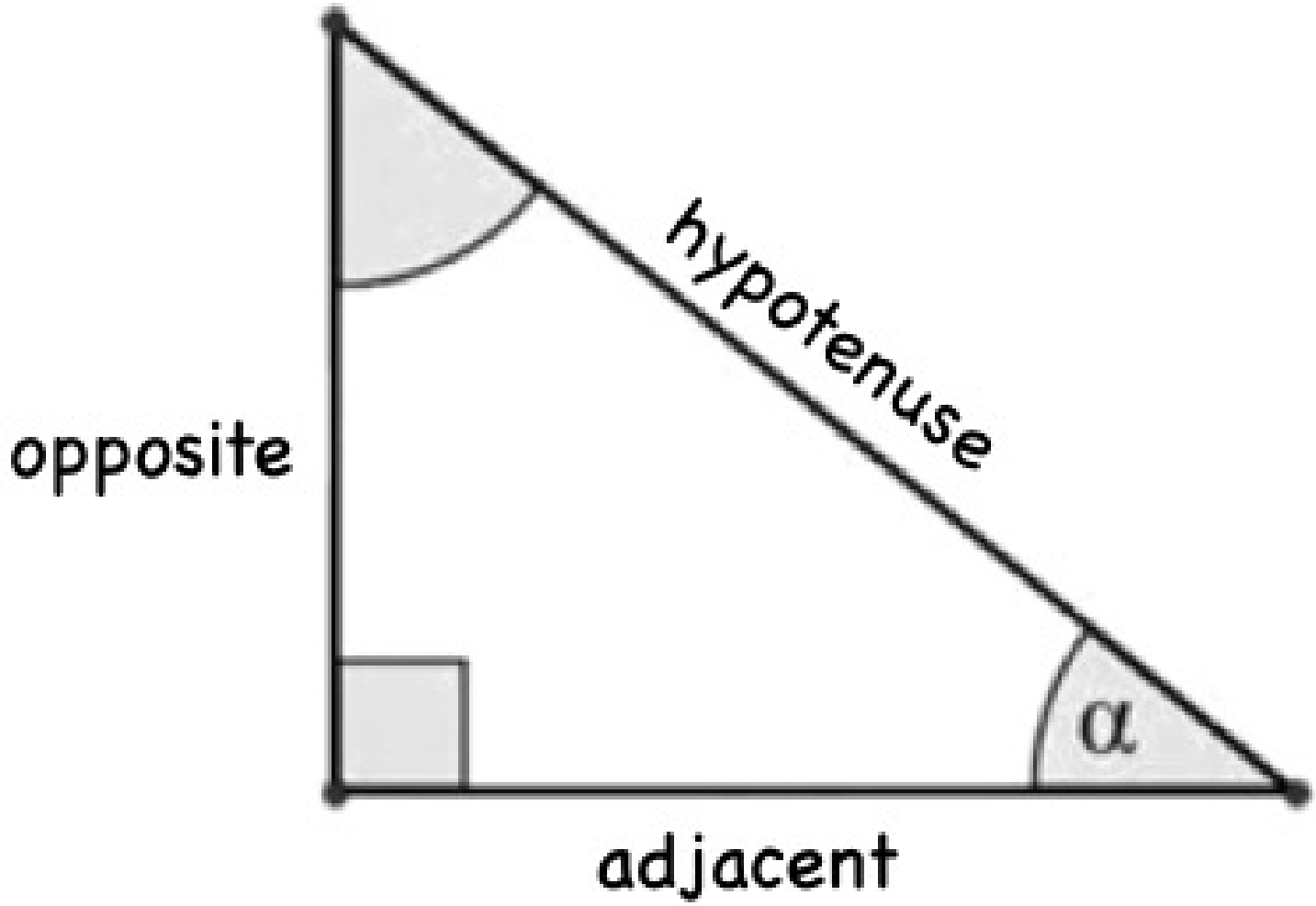
Hypotenuse = *trajectory*

Adjacent side = distance to shooter (*muzzle)*

Opposite side = *height of muzzle above/below impact or lateral distance* *(azimuth calculation)*

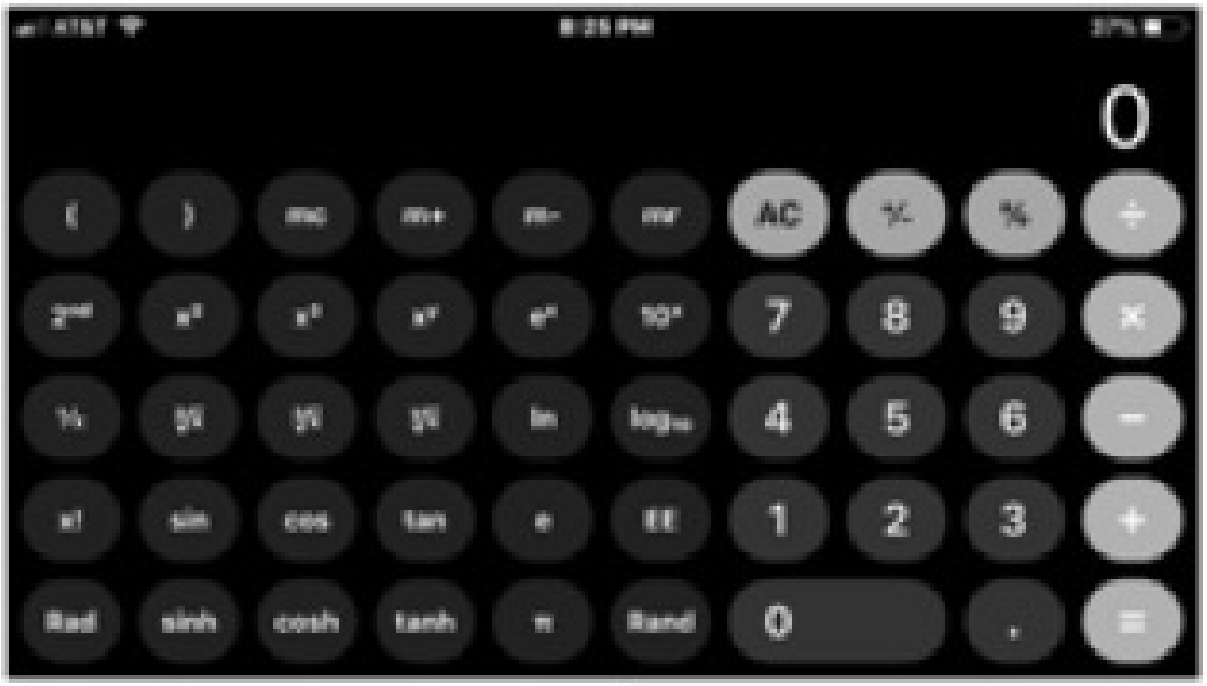


Relationships of Angles to Sides of Triangle



$$sin = \frac{opposite}{hypotenuse}$$

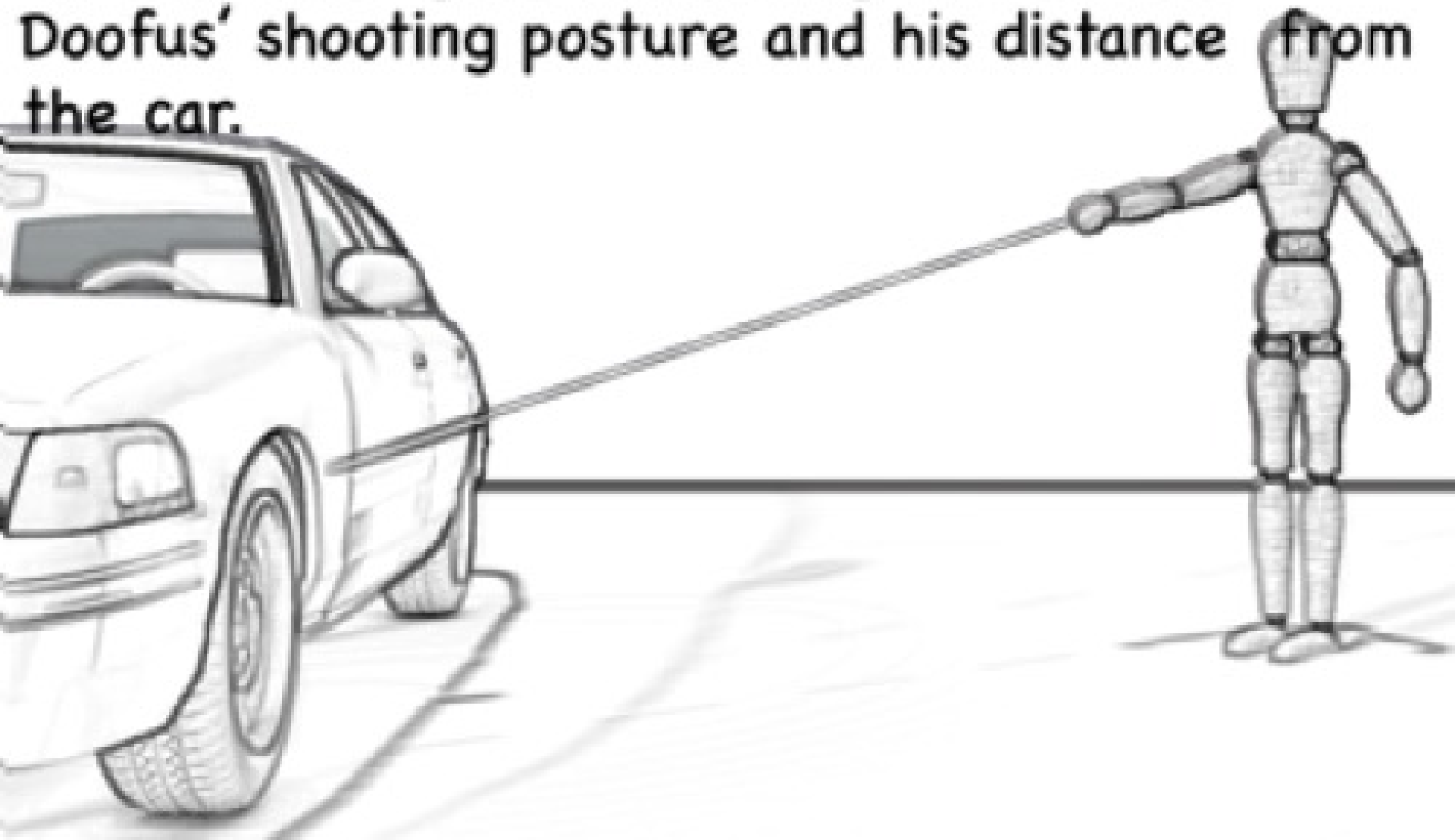
$$tangent = \frac{opposite}{adjacent}$$



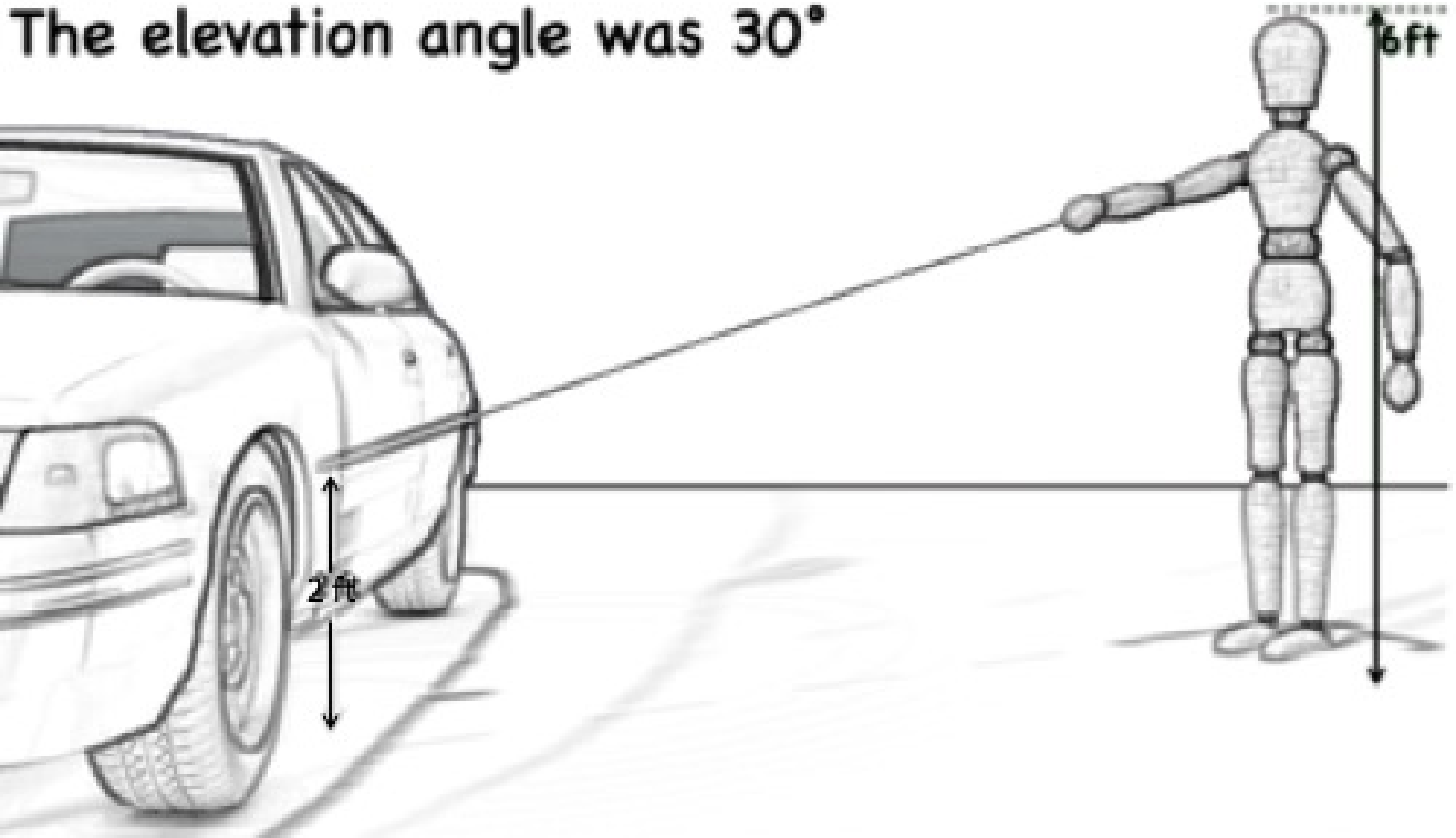
37, sin, ----- 0.6018

0.6018, sin,---- 37

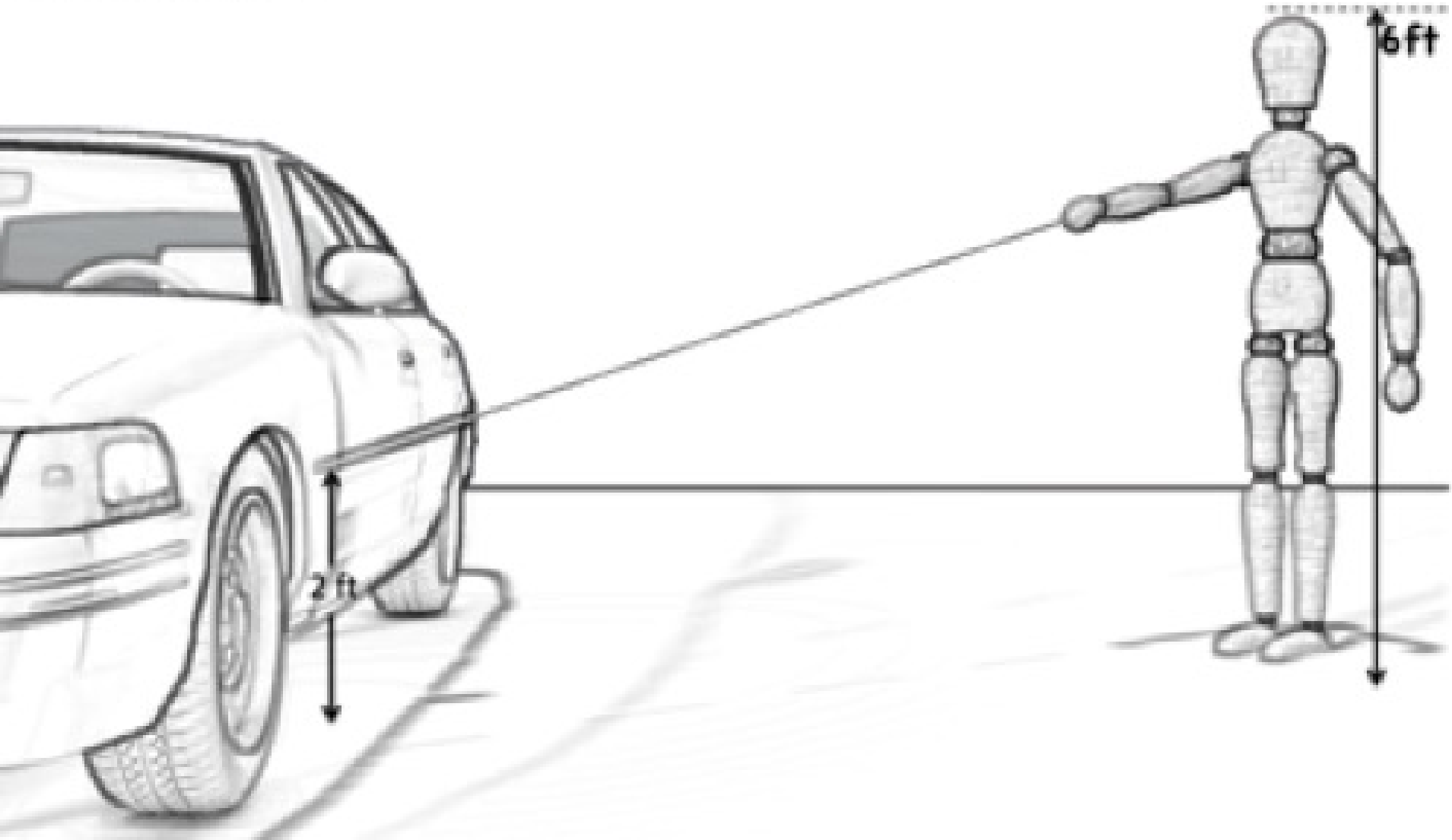
Doofus was observed shooting a car in the parking lot.
Eyewitnesses gave conflicting accounts of Doofus' shooting posture and his distance from the car.



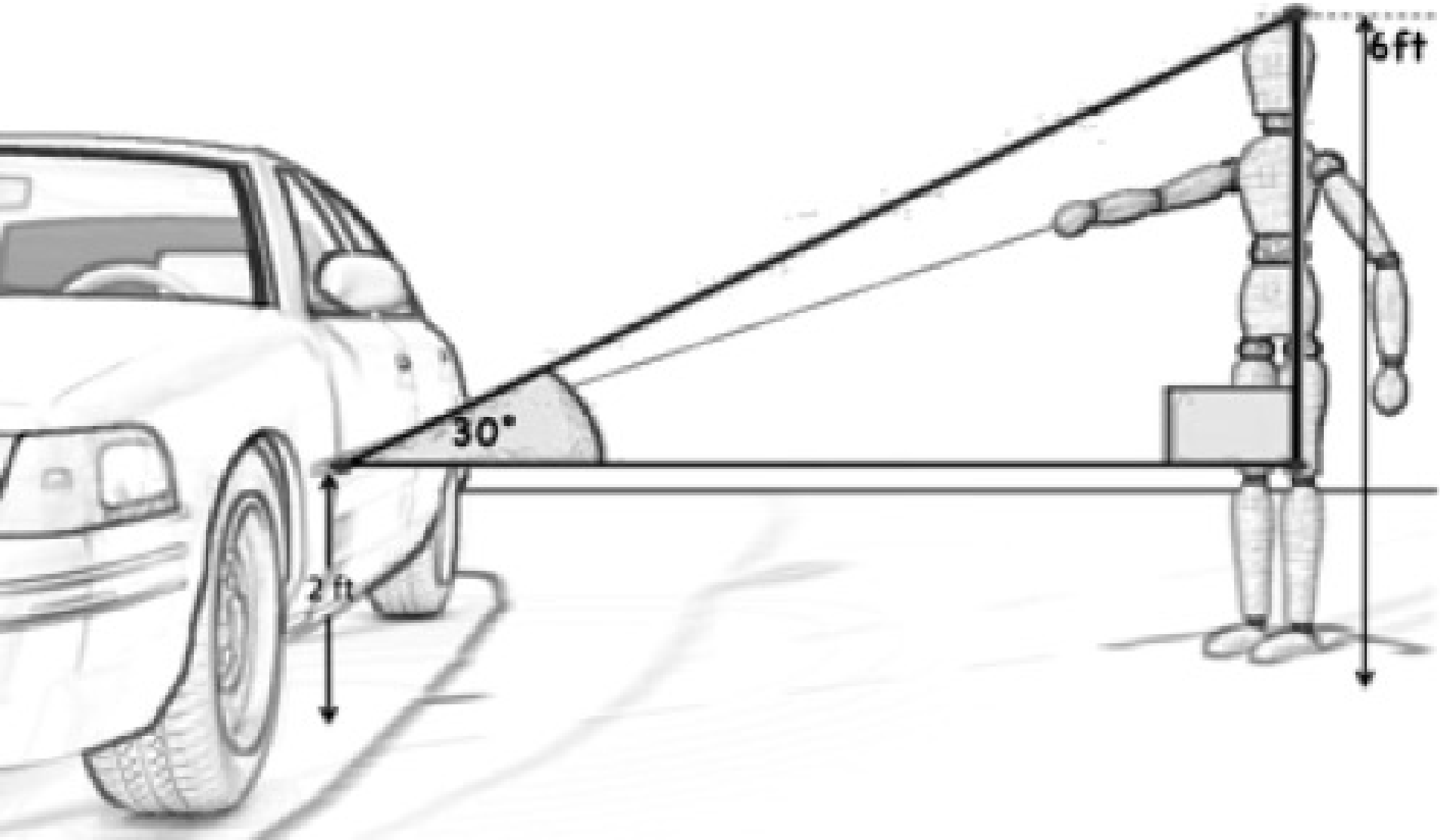
Doofus is 6ft tall.
The height of the bullet defect in the car is 2ft.
The elevation angle was 30°



Calculate the **maximum** distance Doofus' firearm was from the car at time the firearm was discharged.



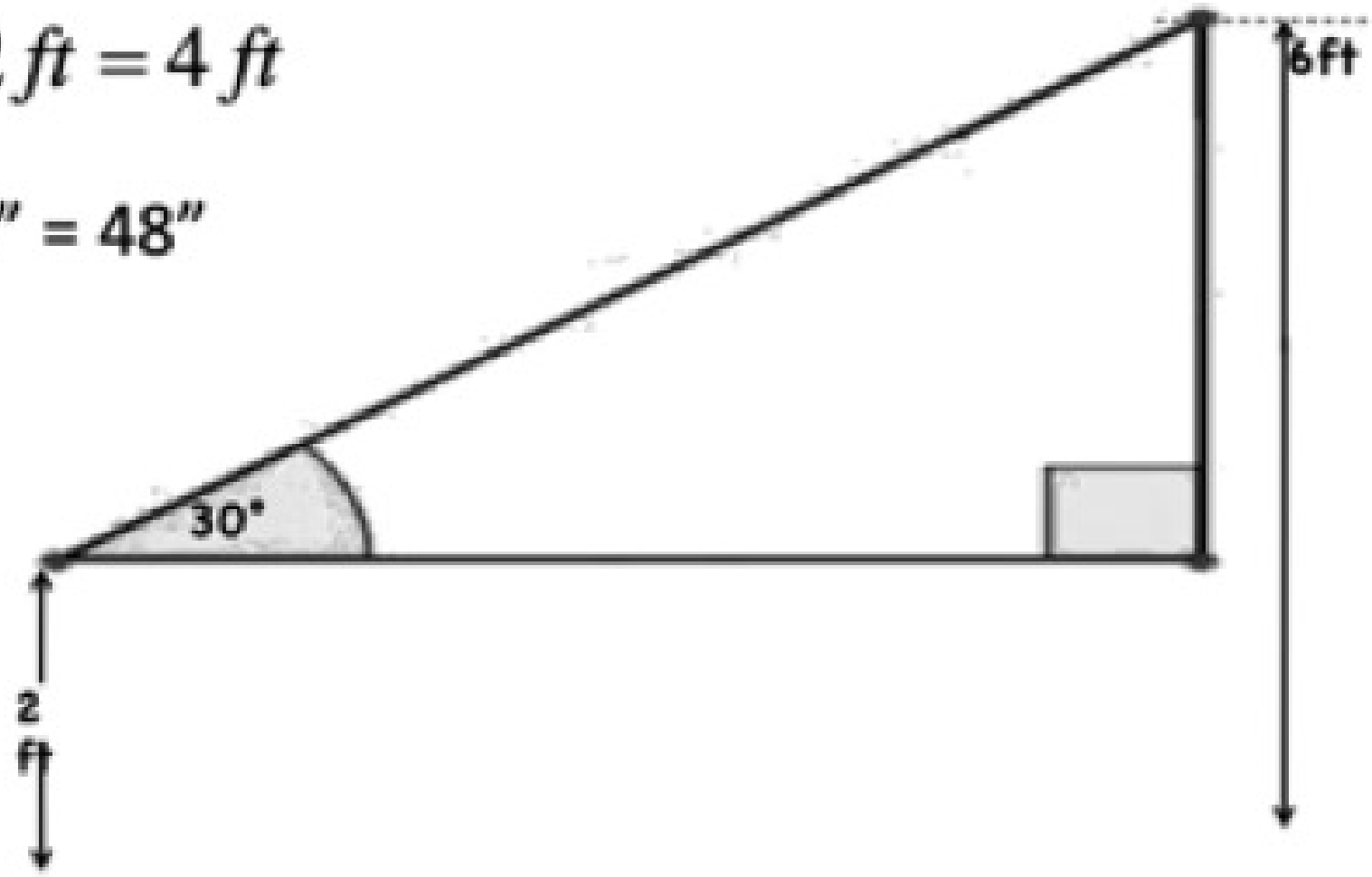
Placing the triangle in the scene image can help you maintain perspective!



What is the height of the opposite side of this triangle?

$6\,ft - 2\,ft = 4\,ft$

72"-24" = 48"



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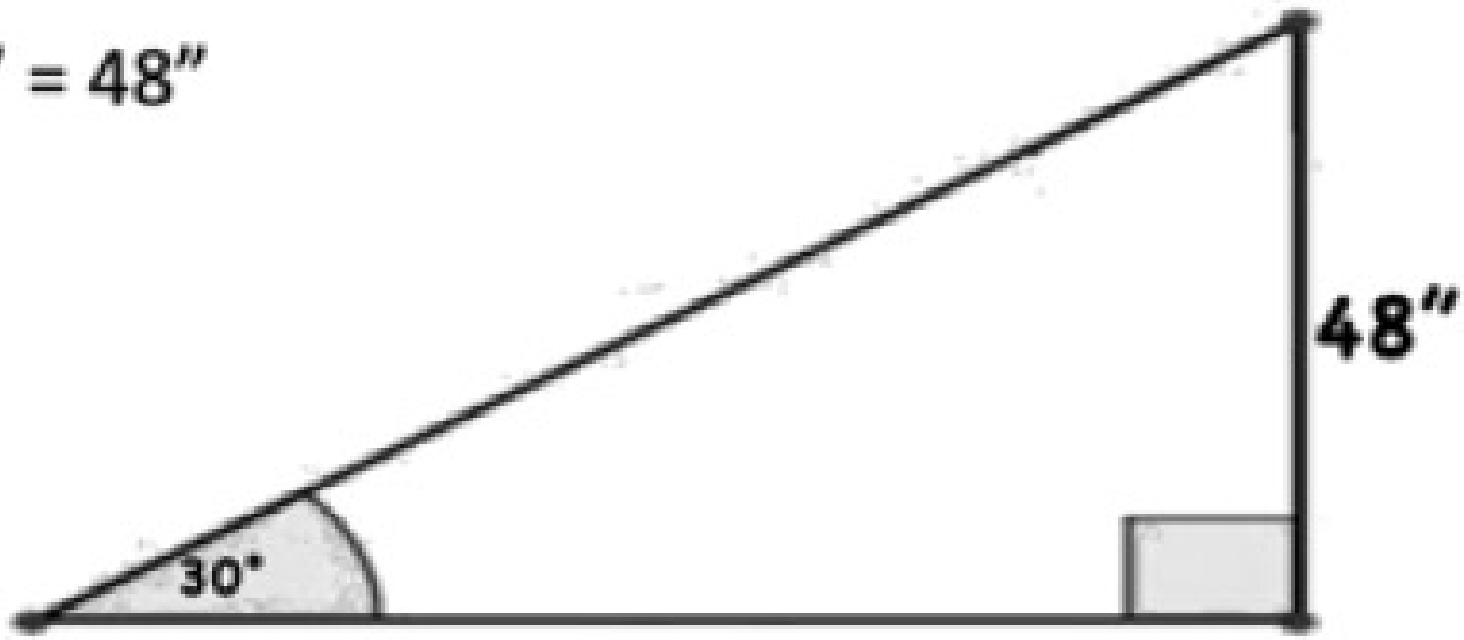

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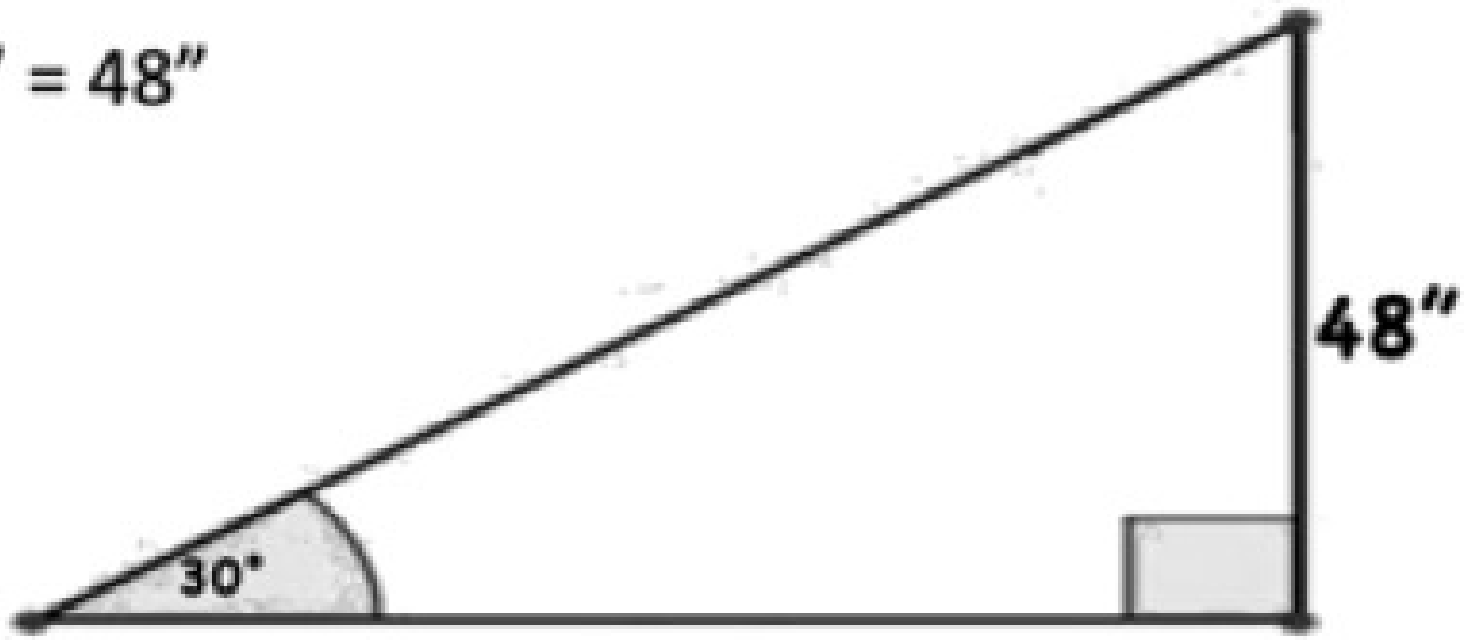


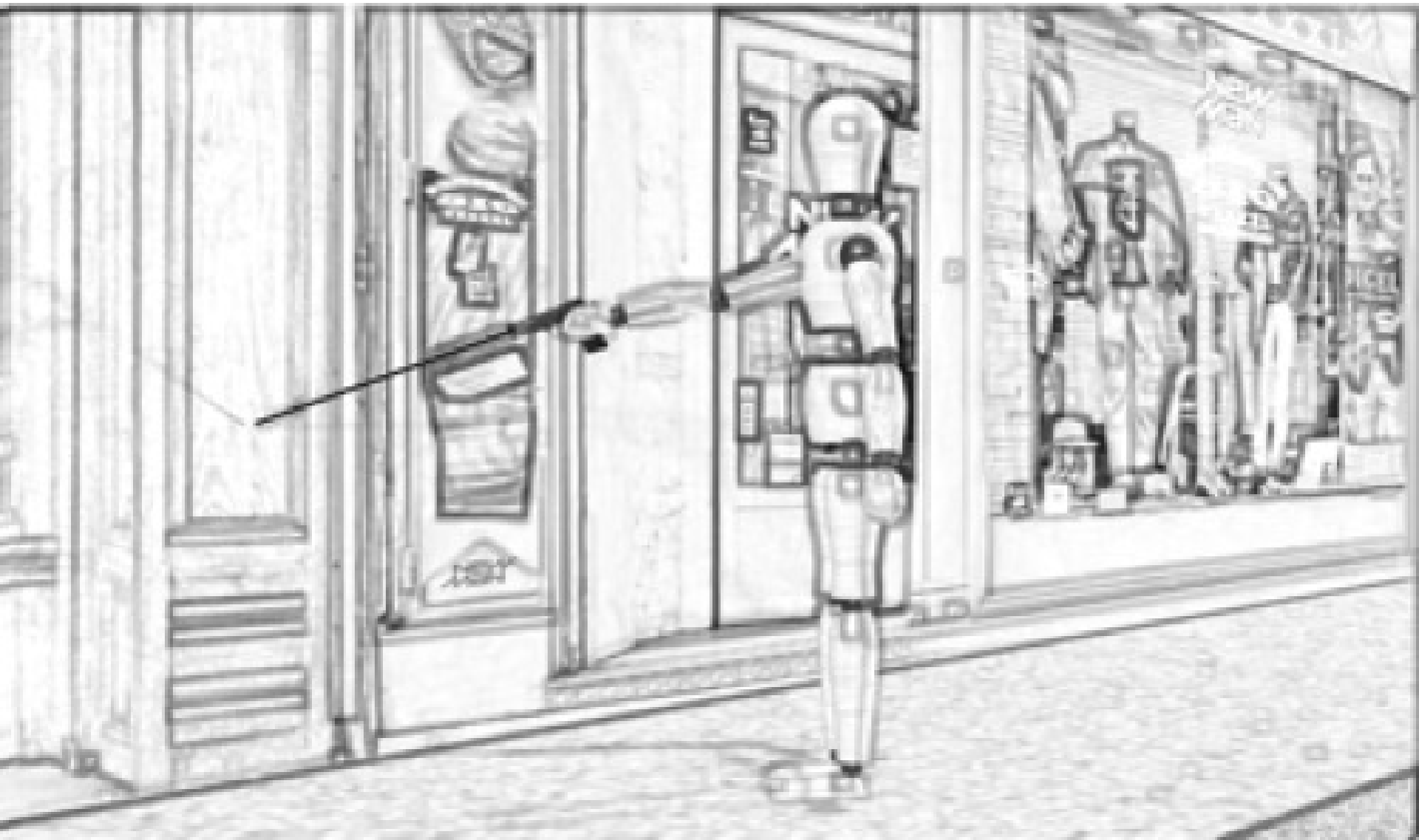
"Cheat Sheet" for Tangent Formula

$$\tan\theta = \frac{opposite}{adjacent}$$

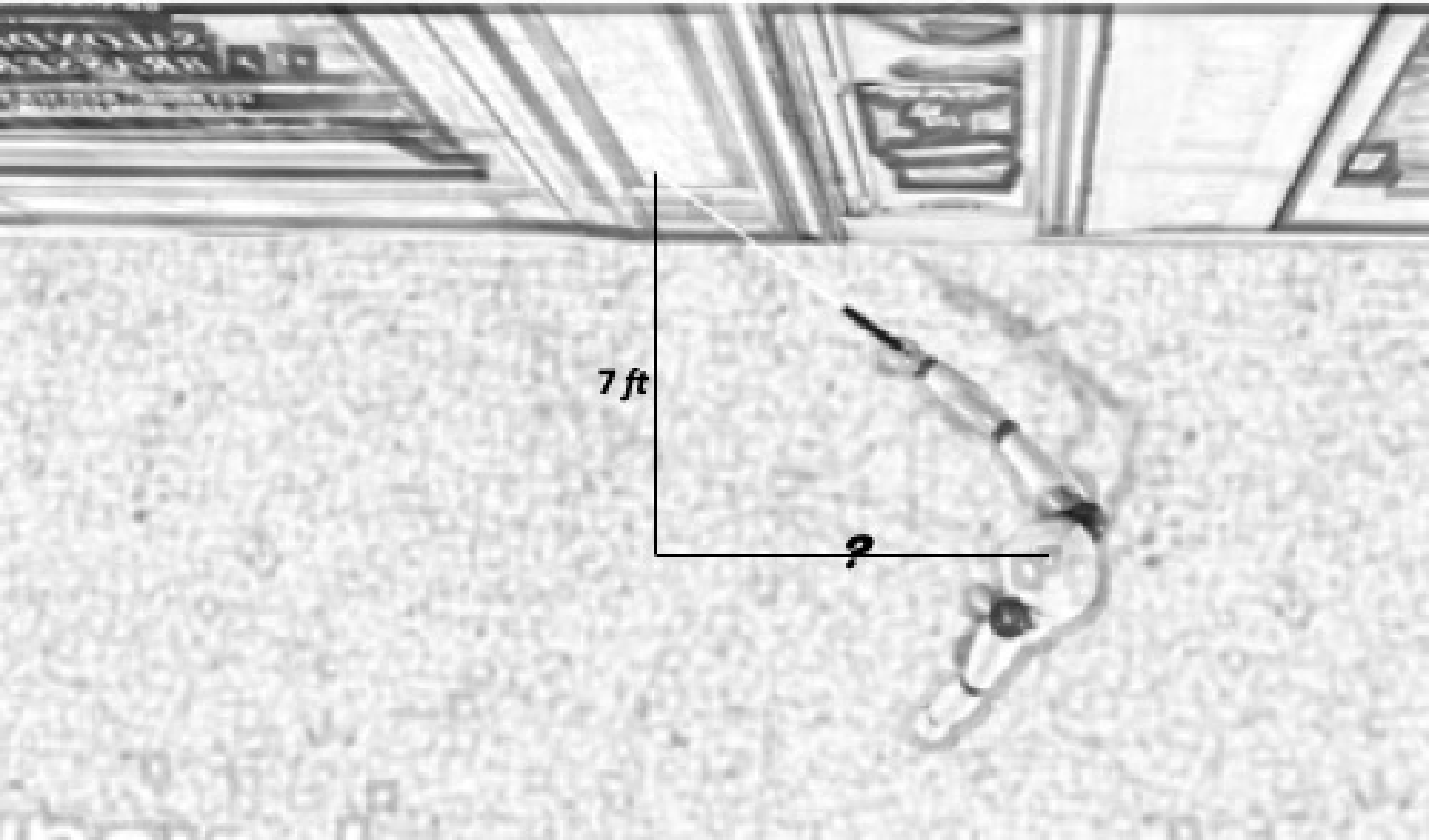
$$opposite = \tan\theta \times adjacent$$

$$adjacent = \frac{opposite}{\tan\theta}$$

Doofus was observed shooting a storefront. Eyewitnesses gave conflicting accounts of Doofus' shooting position and posture.



If Doofus was 7 ft from the wall, but fired at a 30° angle to the wall, (R-L) what was his distance to the right of the defect?



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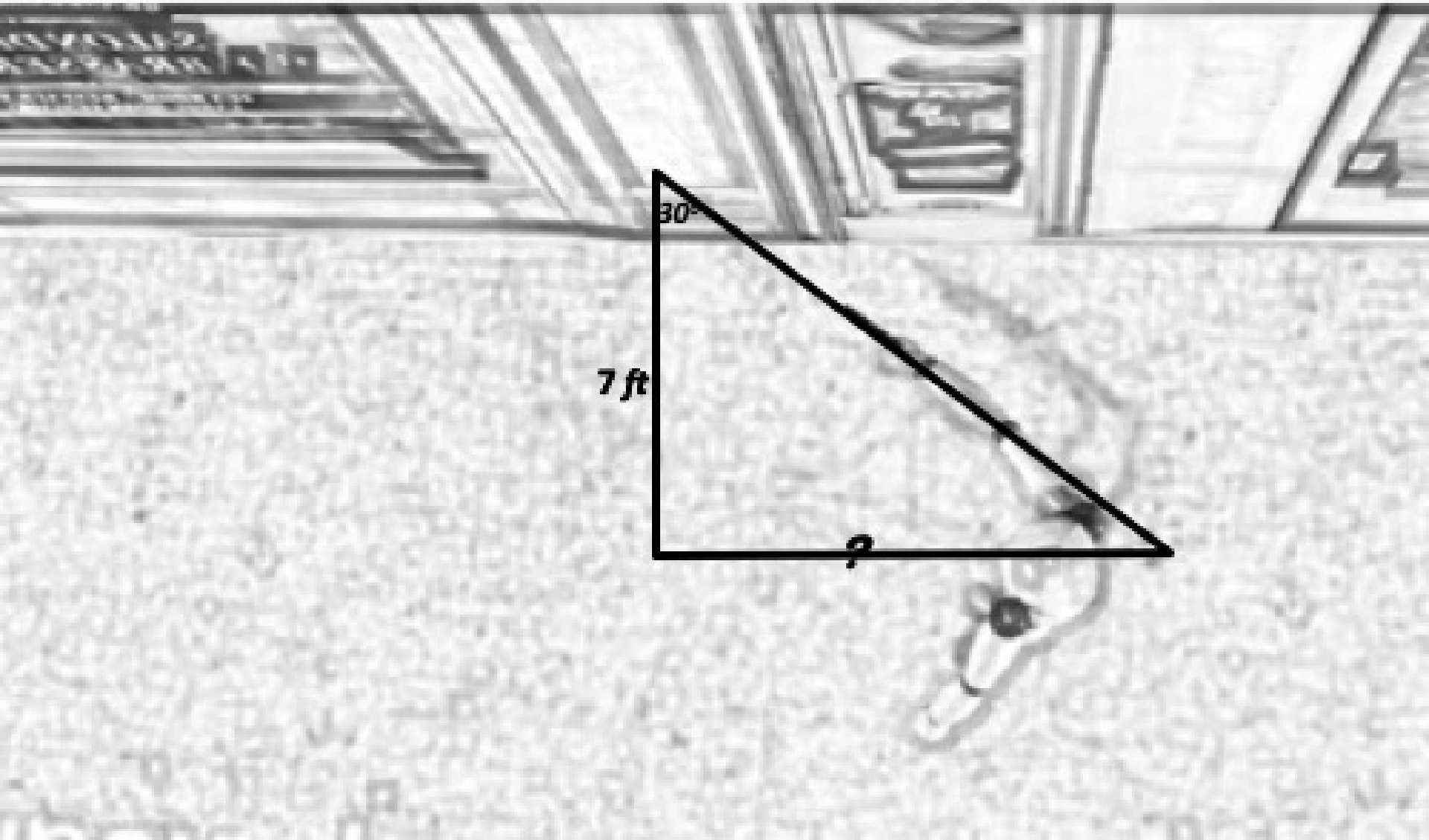
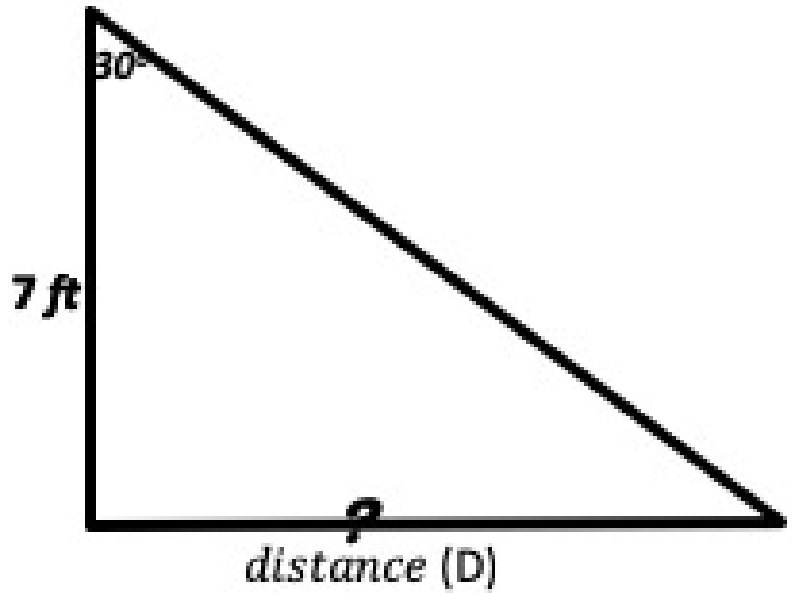


Doofus was 7 ft from the wall. What was his distance to right of the defect?

Opposite=adjacent x tangent 30^o

$distance = 7$ ft x 0.5774 = 4ft

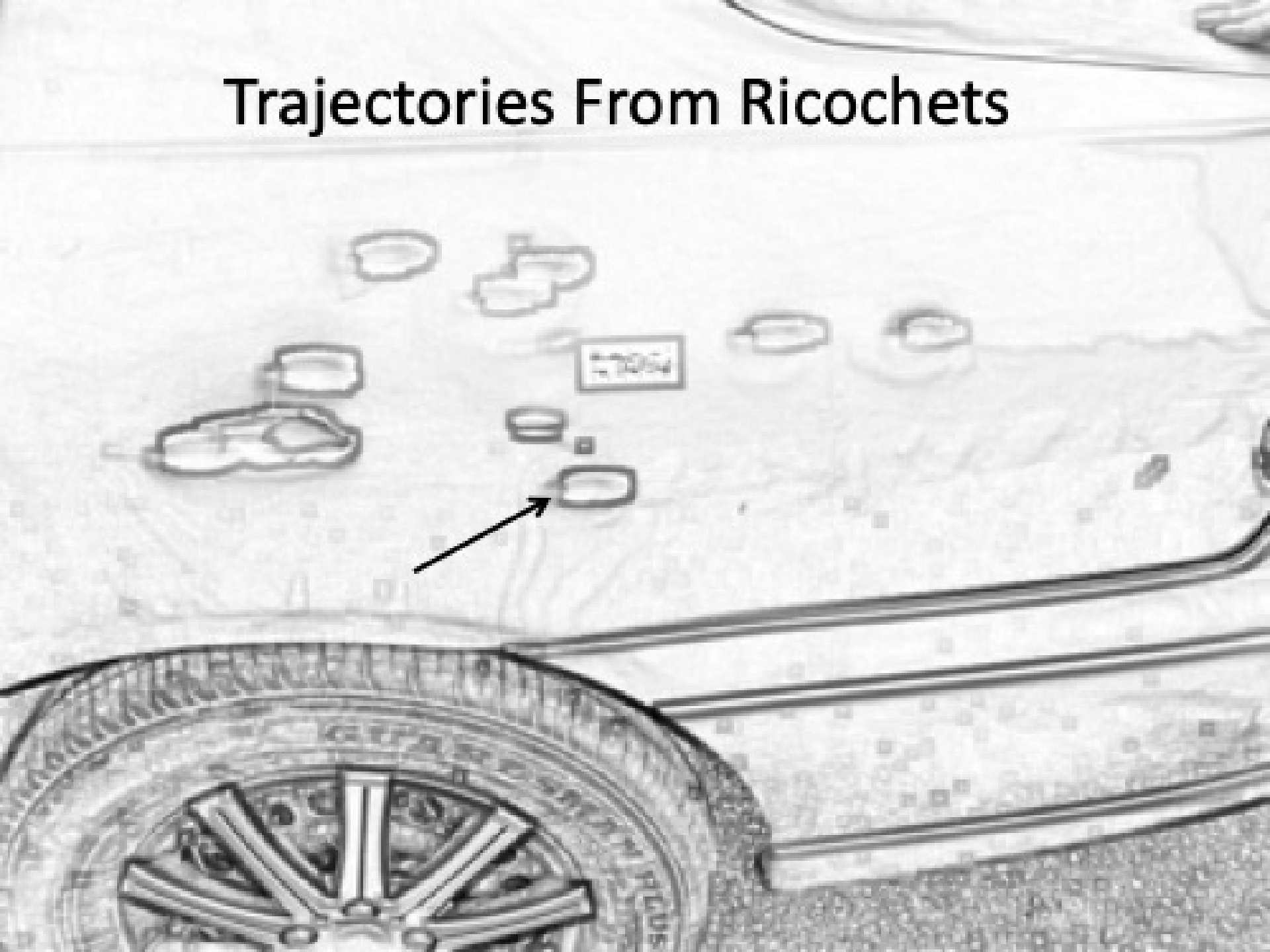


$$tangent = \frac{opposite}{adjacent} \qquad adjacent = \frac{opposite}{tangent}$$

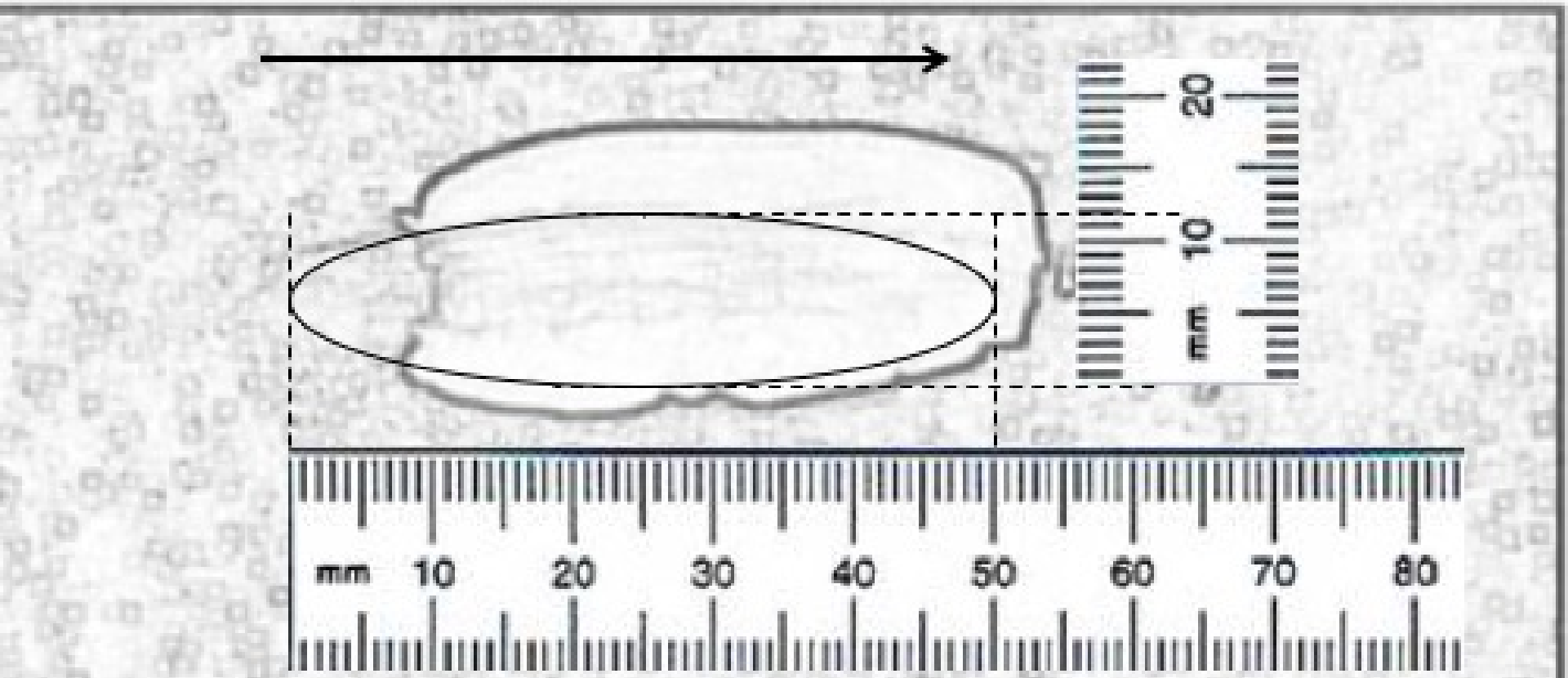
Doing the Math – Tips for Success

- Convert all data to inches
  - Work through problem, then convert answer.
- Round fractions to four decimal places
  - Tan 30^{o} = 0.5774
  - Include the 0 in decimals…. **0**.3476
- In most cases, round degrees to closest degree.
- Visualization – Draw pictures.
- Audit work. Mistakes begat mistakes.

Trajectories From Ricochets



Incident Angle from Sin Method



$$\frac{width}{length} = \sin\vartheta$$

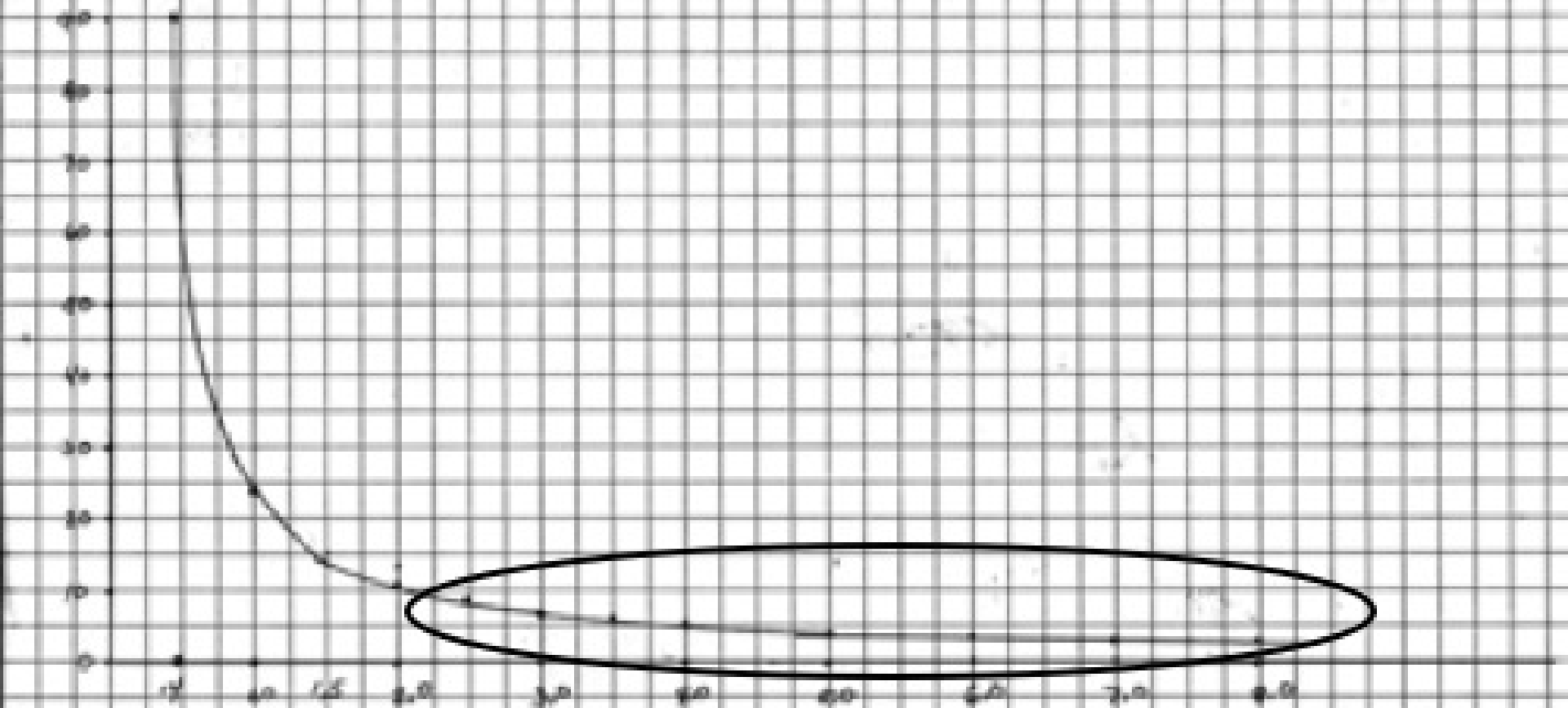
$$\frac{12\text{ mm}}{50\text{mm}} = 0.24$$

14 degrees

BULLET DEFECT ANALYSIS

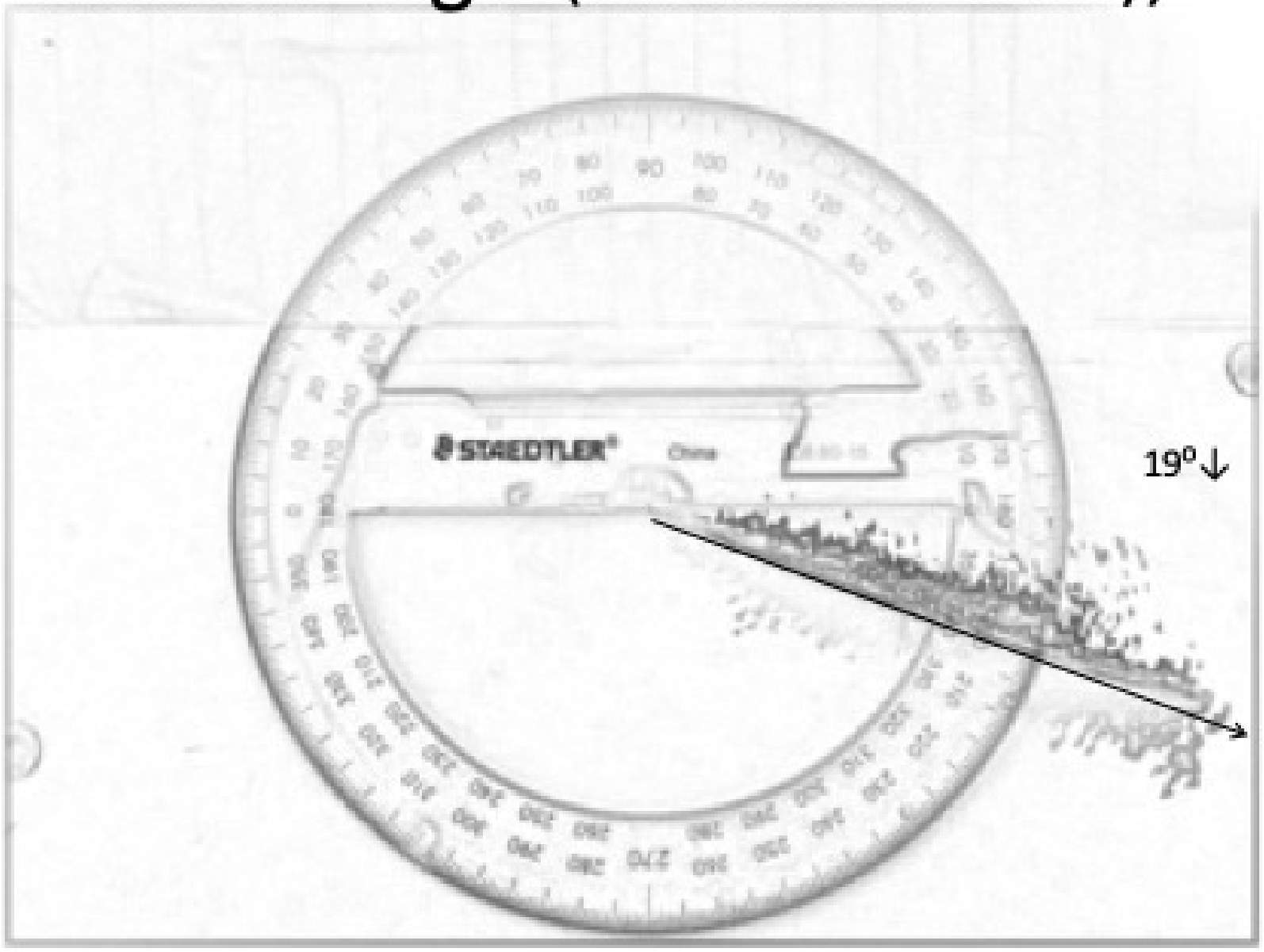
WIDTH = 0.4" = CONSTANT

$\sin \lambda = \frac{W}{L}$ $\quad L = \frac{W}{\sin \lambda}$



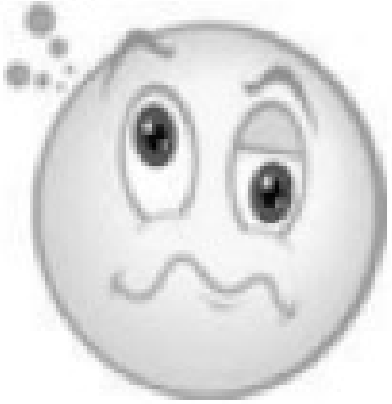
1" = 23.6°	3" = 7.7°	6" = 3.8°
1.5" = 15.4°	3.5" = 6.6°	7" = 3.3°
2" = 11.5°	4" = 5.7°	8" = 2.9°
2.5" = 9.2°	5" = 4.6°	

Elevation Angle (Vertical surfaces only)



Bullet Strike on Intermediate objects

- Ricochet: Continued flight of a rebounded projectile after a low-angle impact with a surface or object. …deflection without penetration or perforation.
  - (Haag 2nd edition p 144)
- Trajectory continues in same plane.
- Deflection: *as result of a ricochet:* departure trajectory in different plane.
  - Lateral deviation

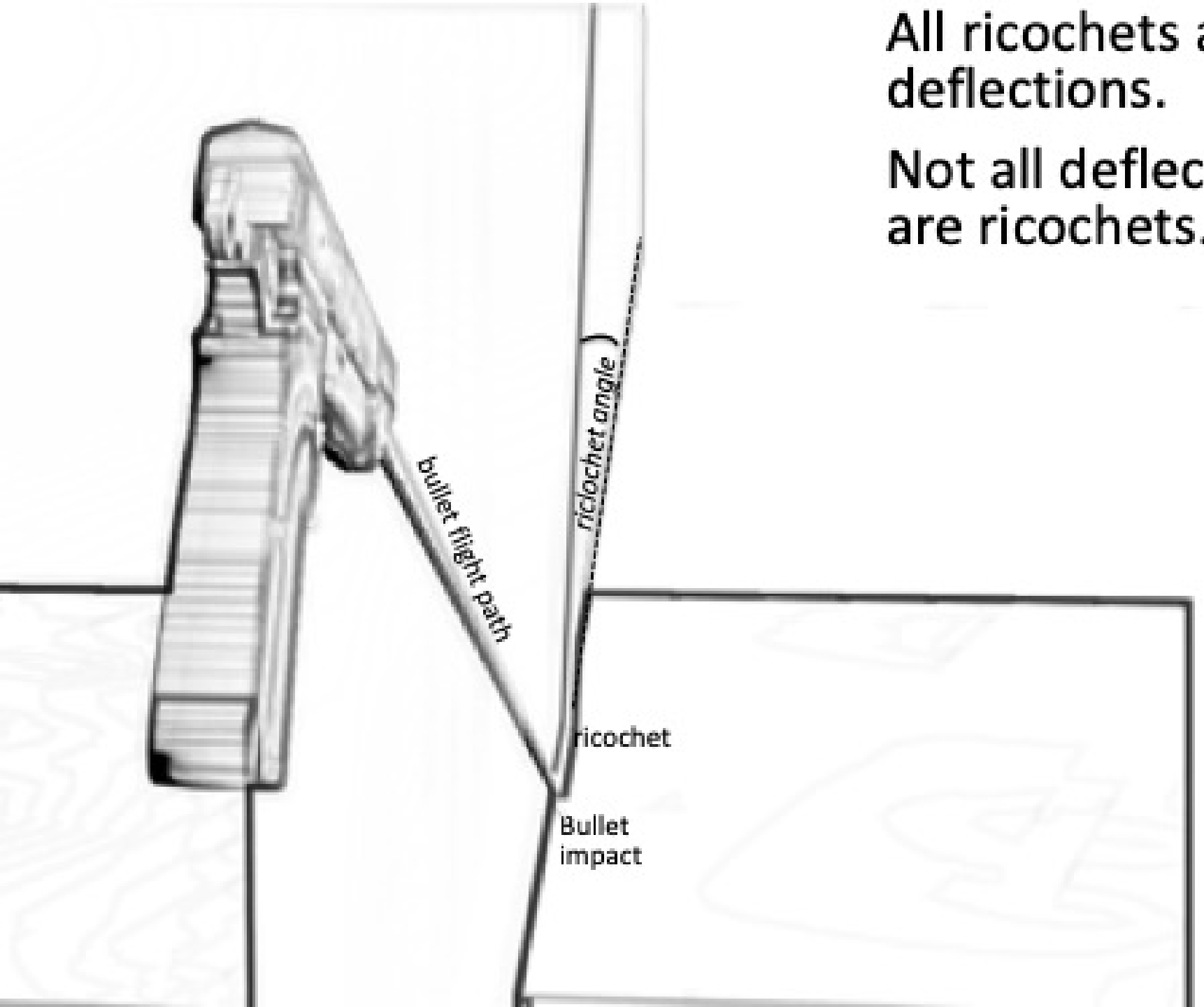


Bullet Strike on Intermediate objects

- Deflection: *as result of perforating or striking an object:* Deviation in <u>any direction</u> from normal flight path.
- Deflection: *as result of a ricochet:* refers to the horizontal or azimuth component of the angle of departure.

All ricochets are deflections.

Not all deflections are ricochets.



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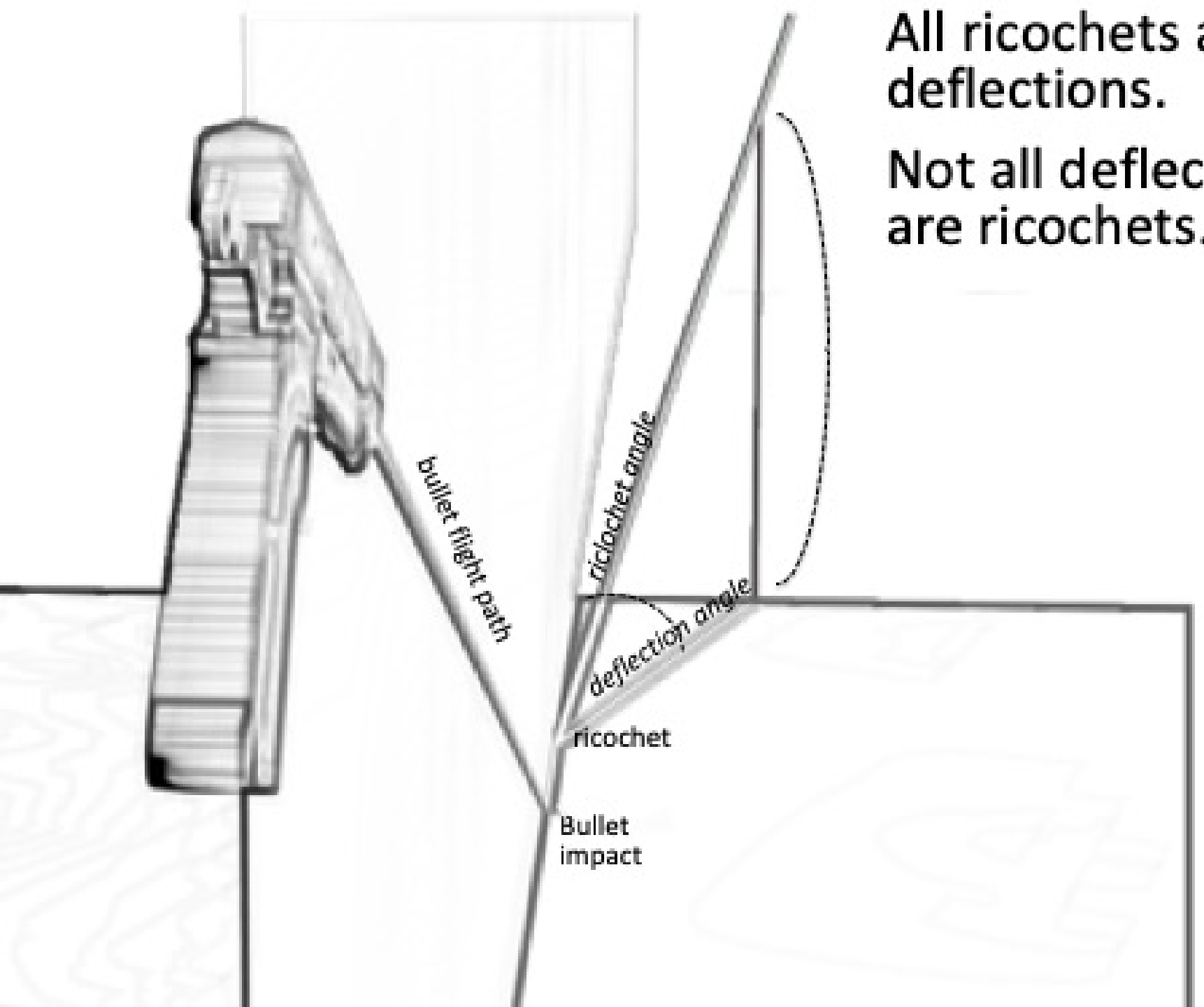
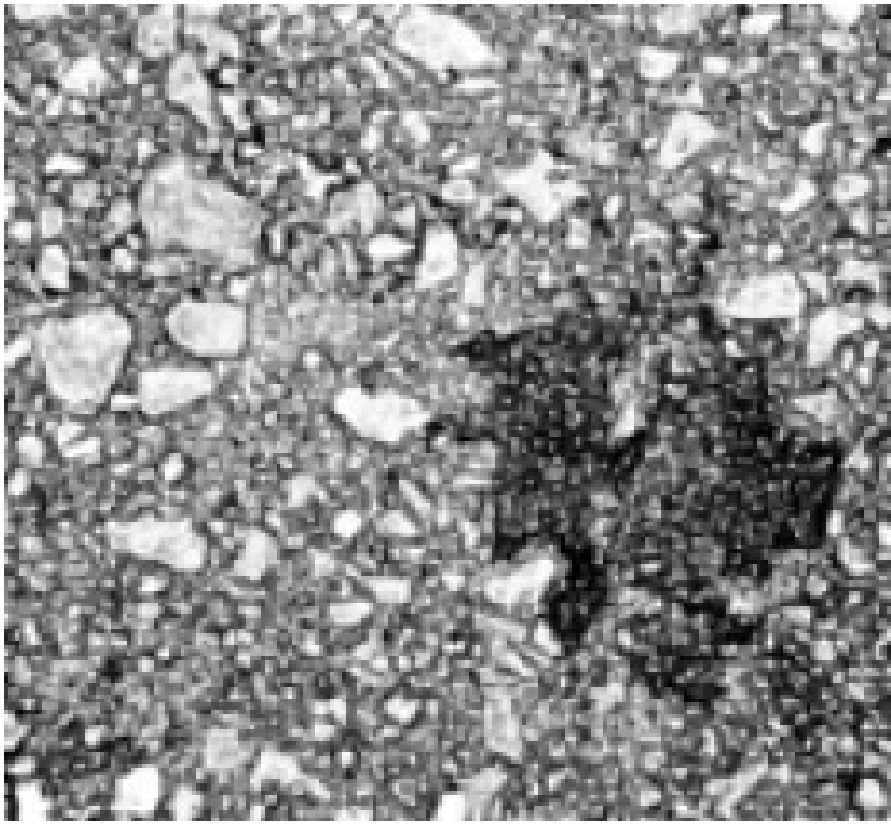
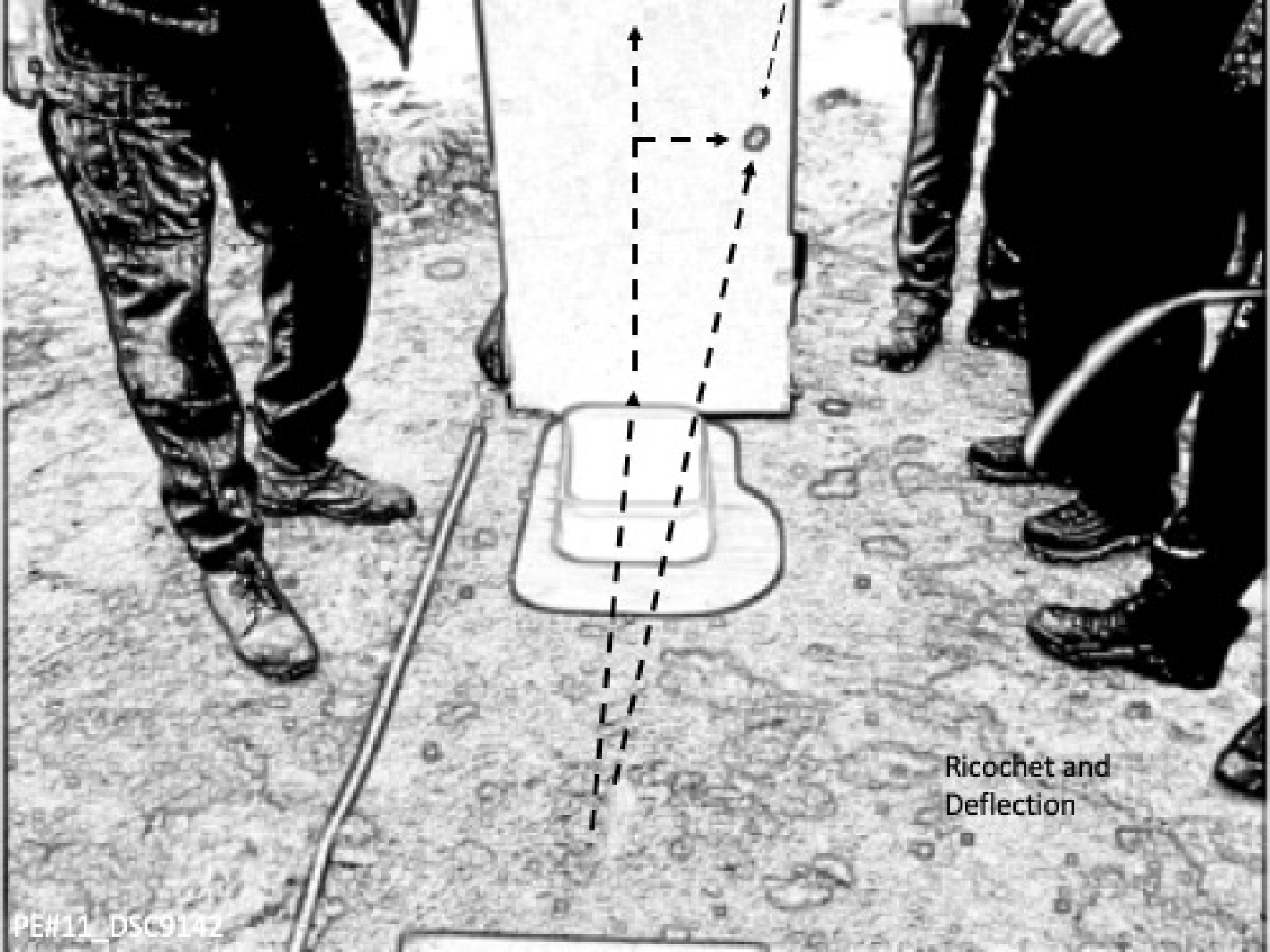


Deflections negligible from ricochets off hard smooth surfaces. (steel, tile, concrete)

Deflections more likely from ricochets off uneven surfaces such as asphalt, sand, dirt.

Asphalt
spawl



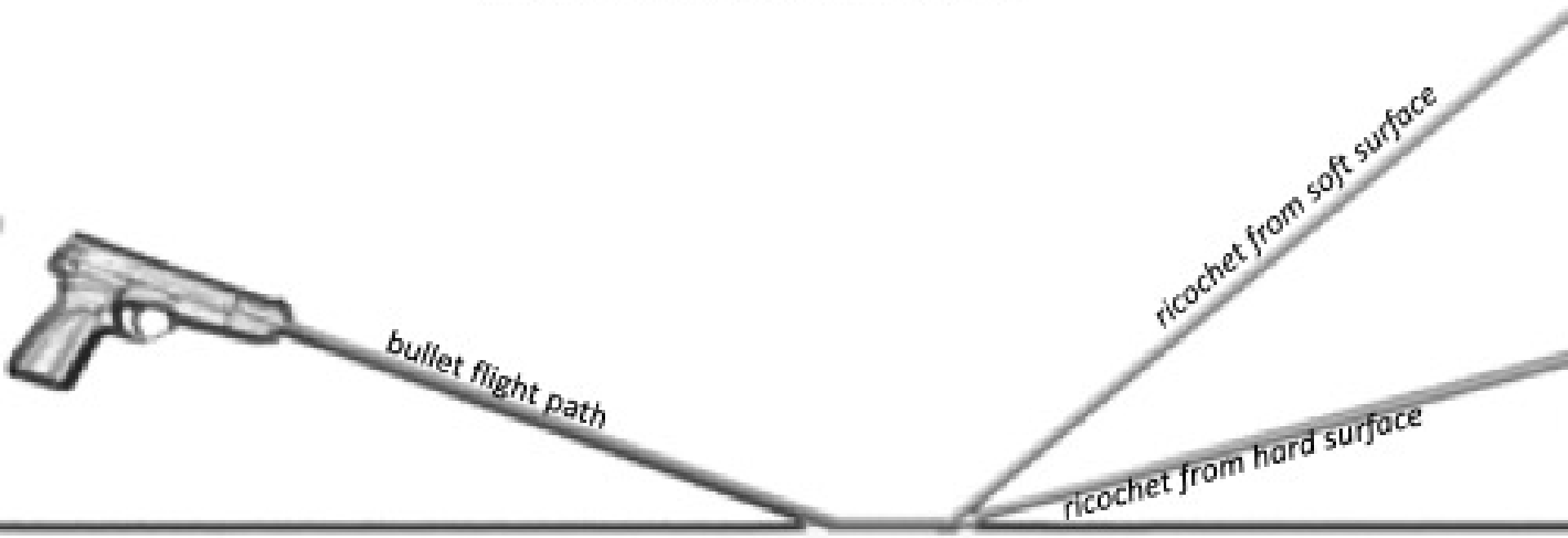


PE#11_DSC9142

Ricochets

Hard surface – Expect lower ricochet angle (steel, concrete)

Softer surface – May have higher ricochet angle (sand, gravel, asphalt)



Ricochets

- Potential evidence at scene from ricochet:
  - Ricochet impact site
    - Directionality, incident angle determination

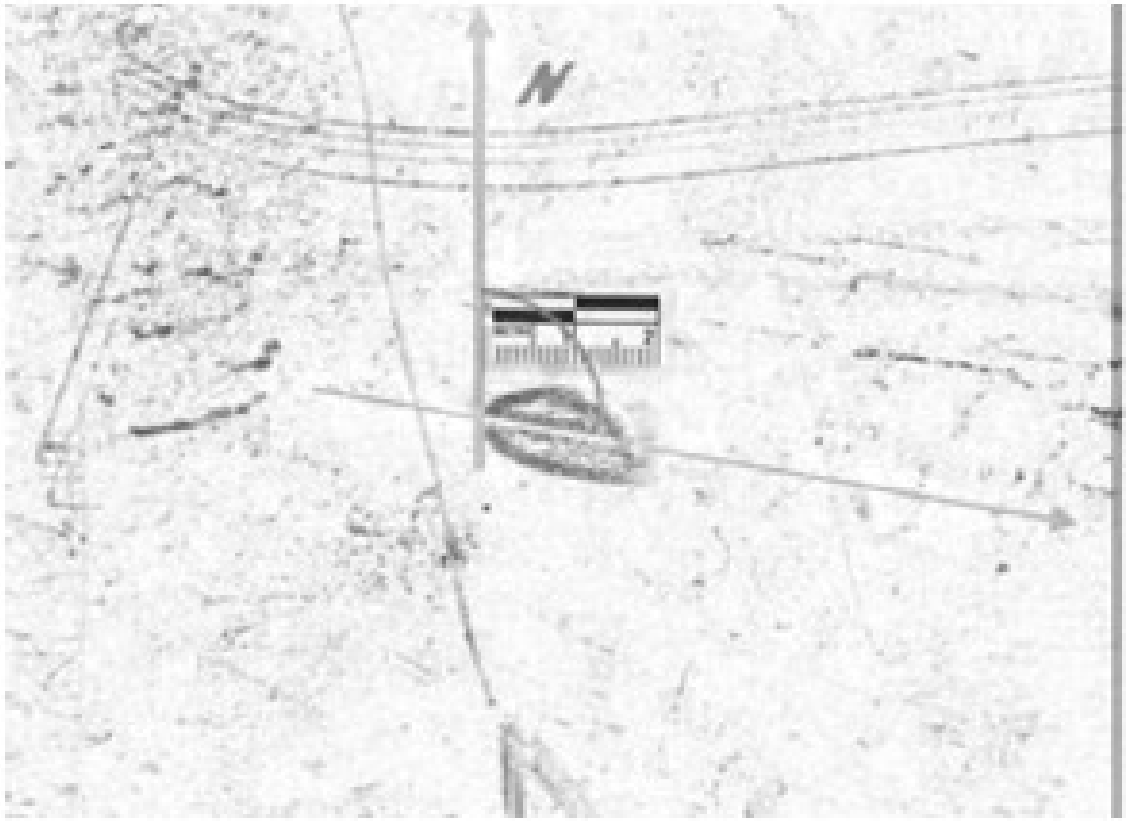
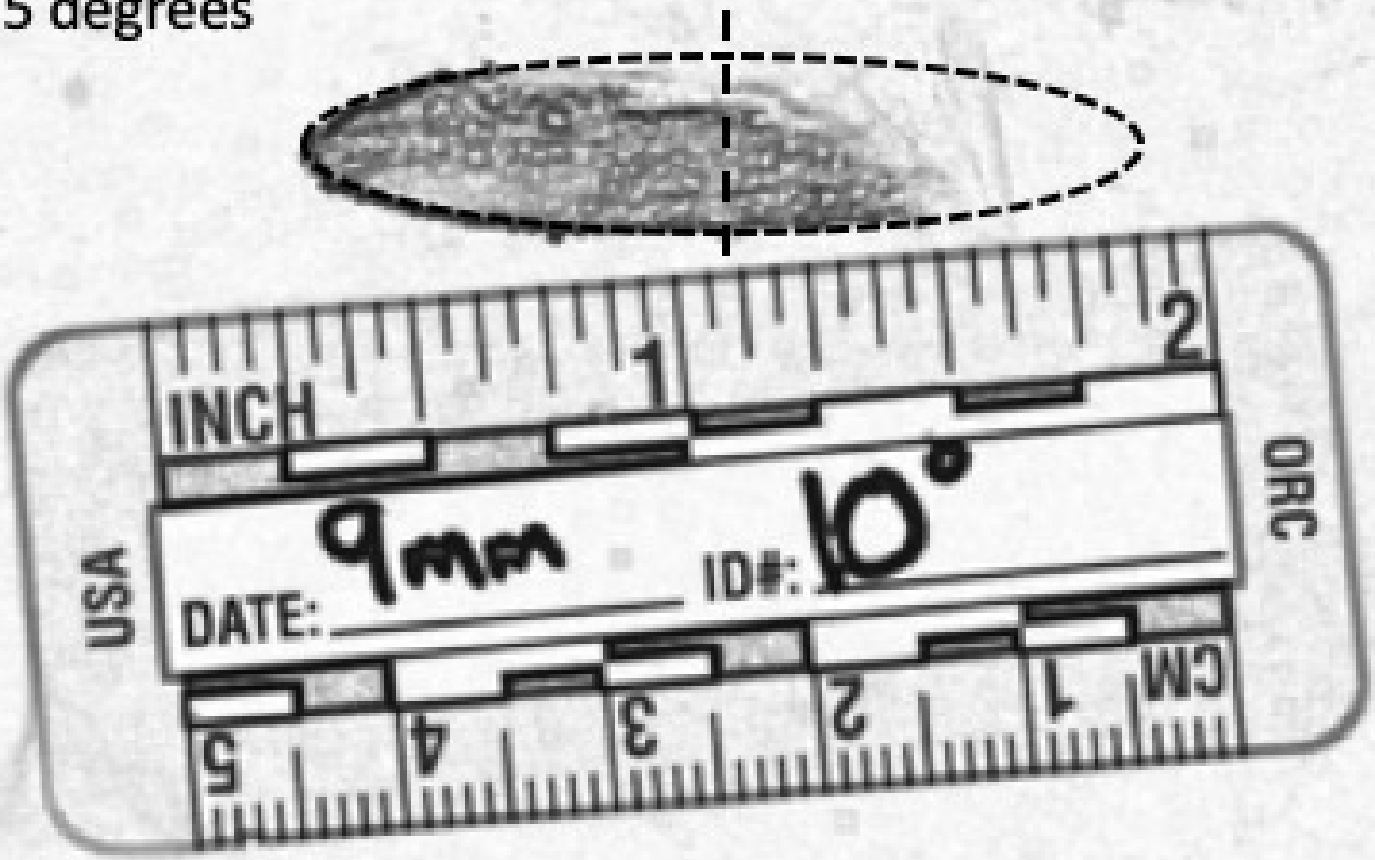


Figure 1 BDF#1 Gamma Angle=101°
(11° from East-West reference)

Ricochet off Plate Steel, Horizontal Surface

Sin Incident Angle = W/L = 8/40 = 0.2000

A=11.5 degrees



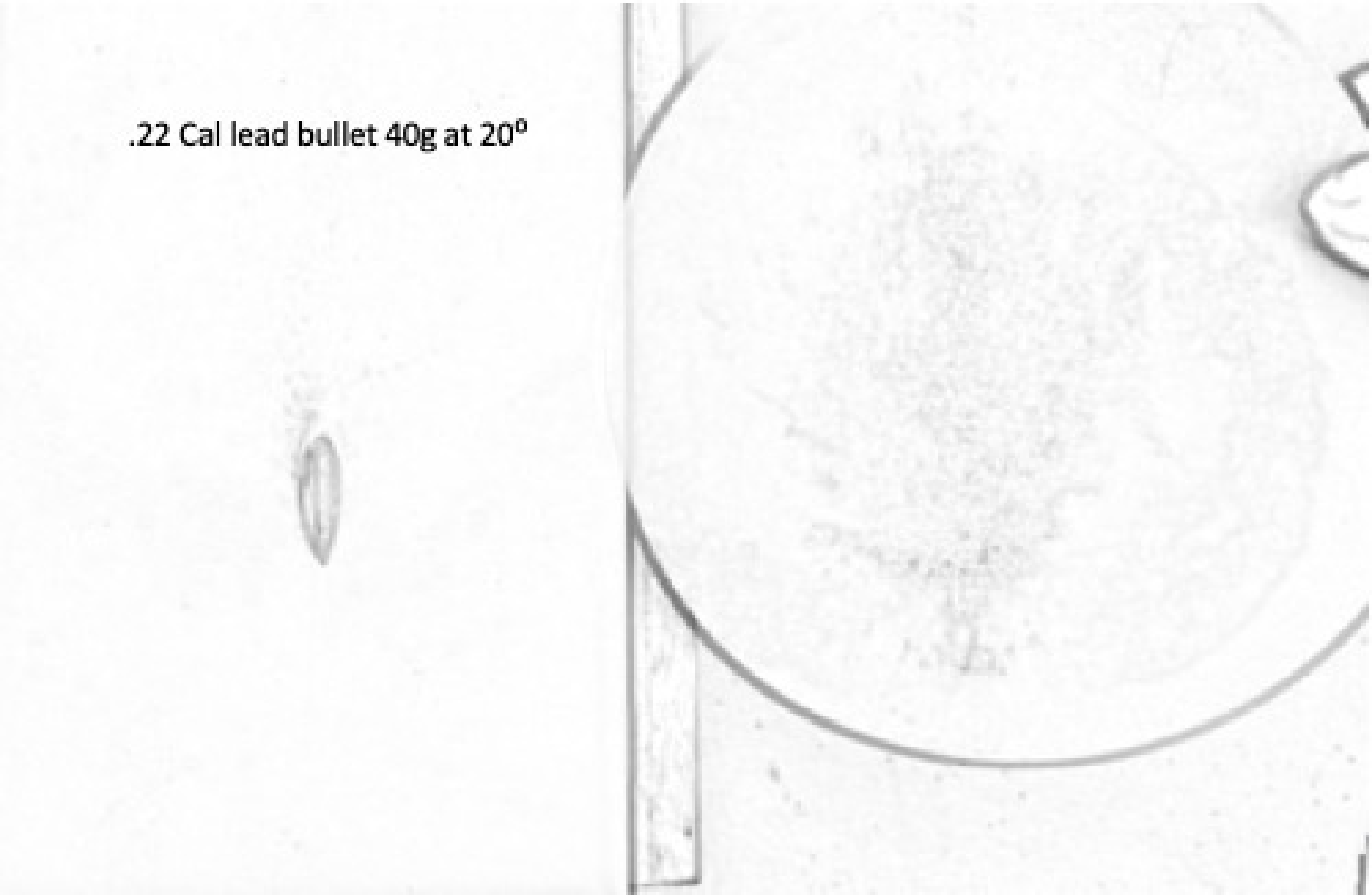
Partial Ellipse: Estimate half and double

Ricochets

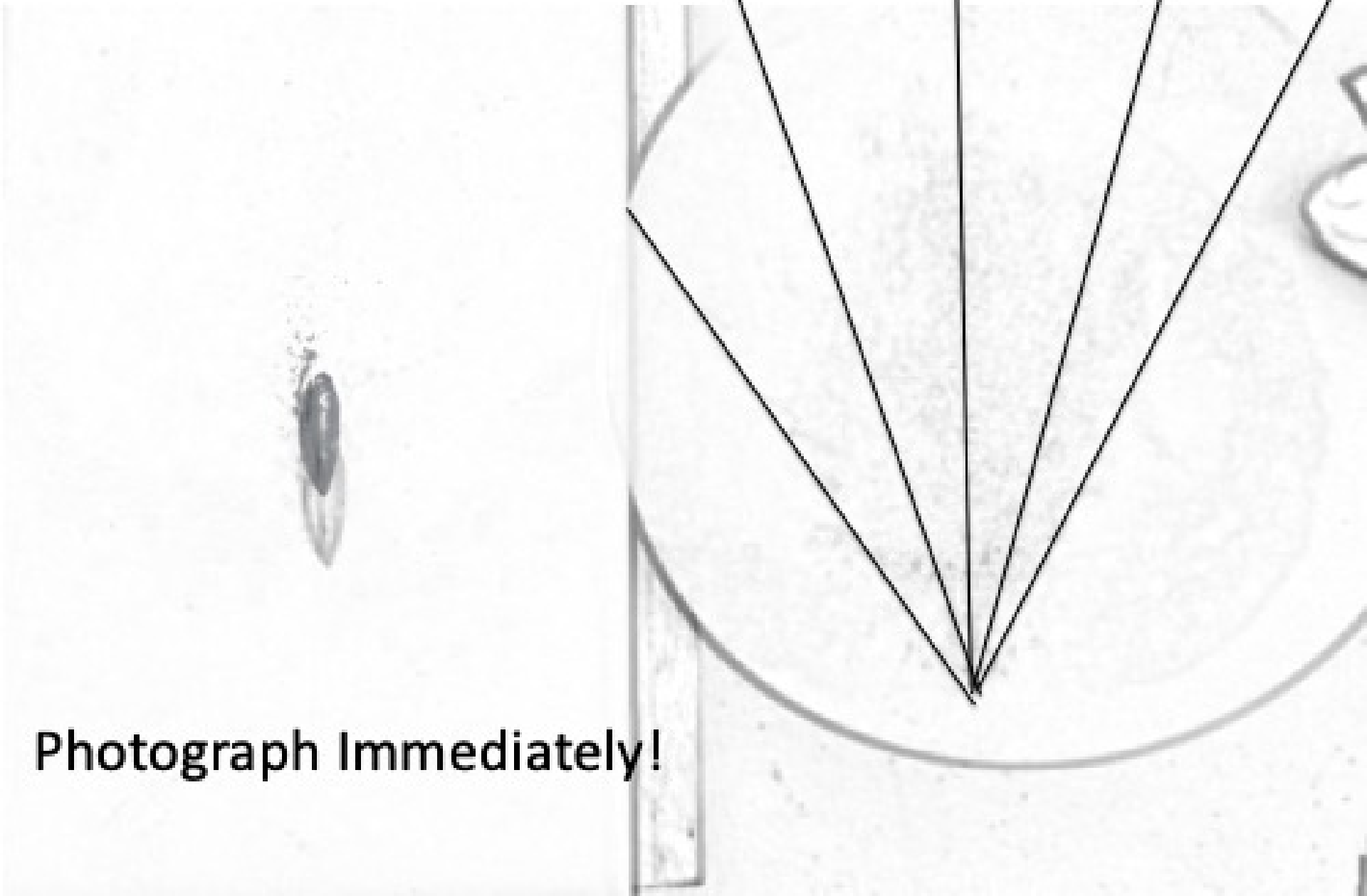
- Potential evidence at scene from ricochet:
  - Ricochet impact site
    - Directionality, incident angle determination
  - Trace evidence
    - Lead splash test

Lead Splash Test

.22 Cal lead bullet 40g at 20°



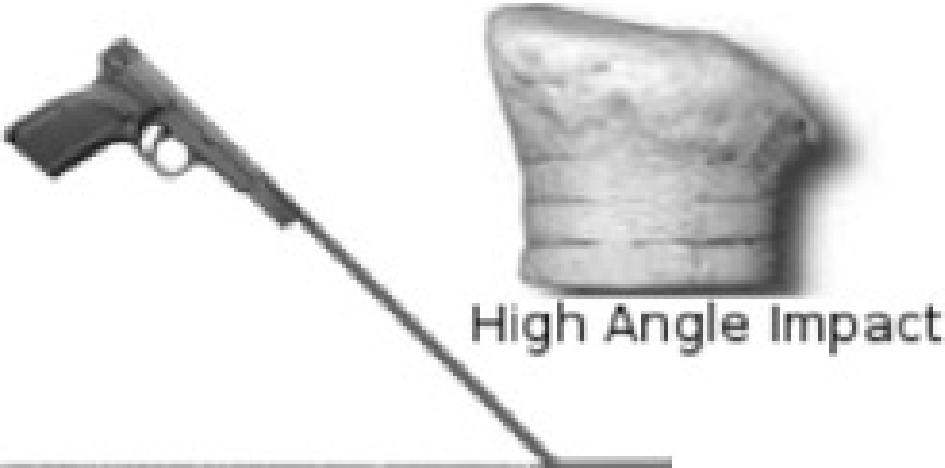
Lead Splash Test - Directionality

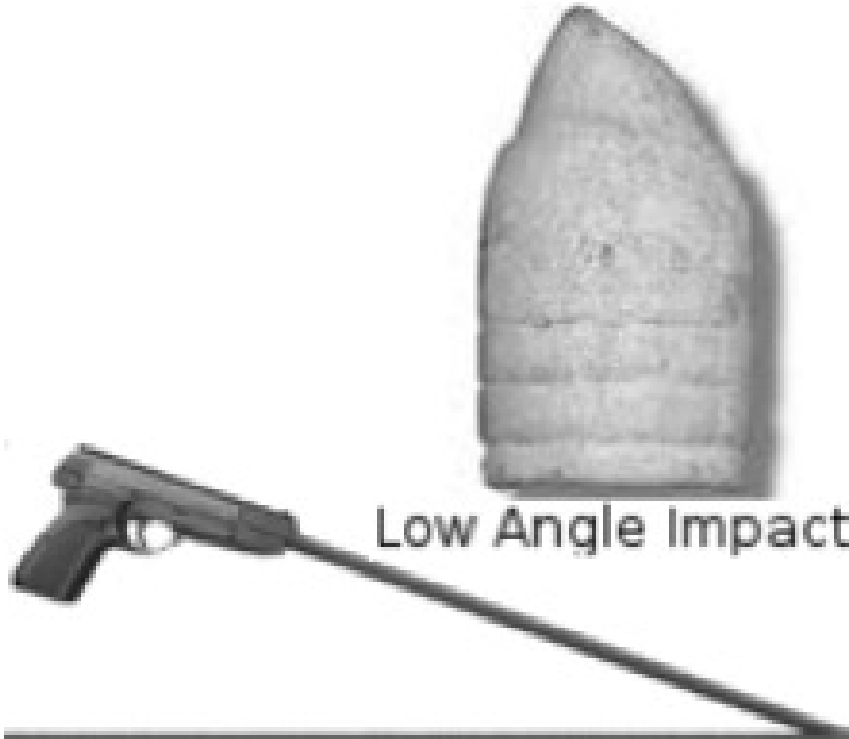


Photograph Immediately!

Ricochets

- Potential evidence at scene from ricochet:
  - Ricochet impact site
    - Directionality, incident angle determination
  - Trace evidence
    - Lead splash test
  - Deformed bullet

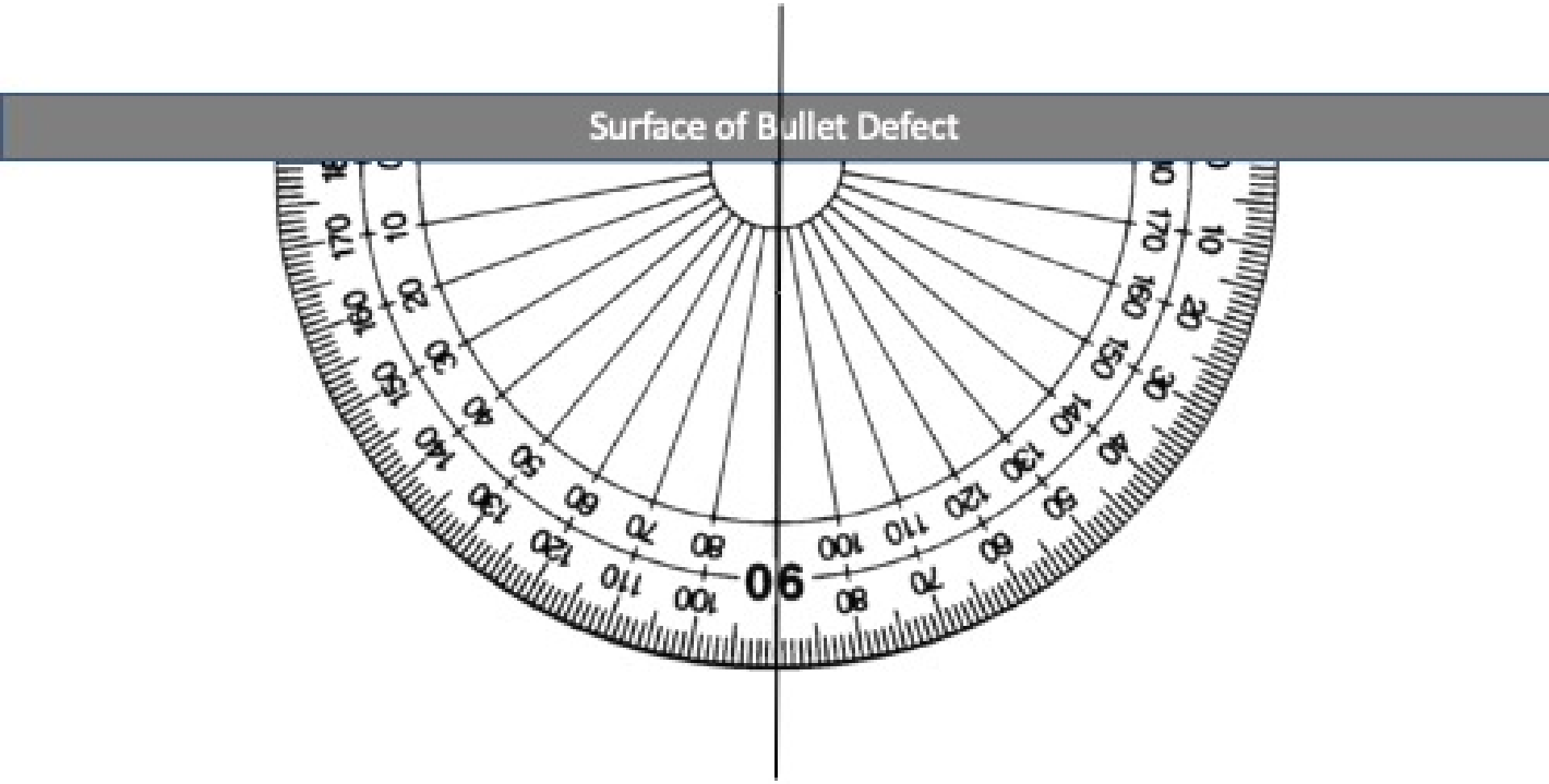




Ricochets – Tips for Success

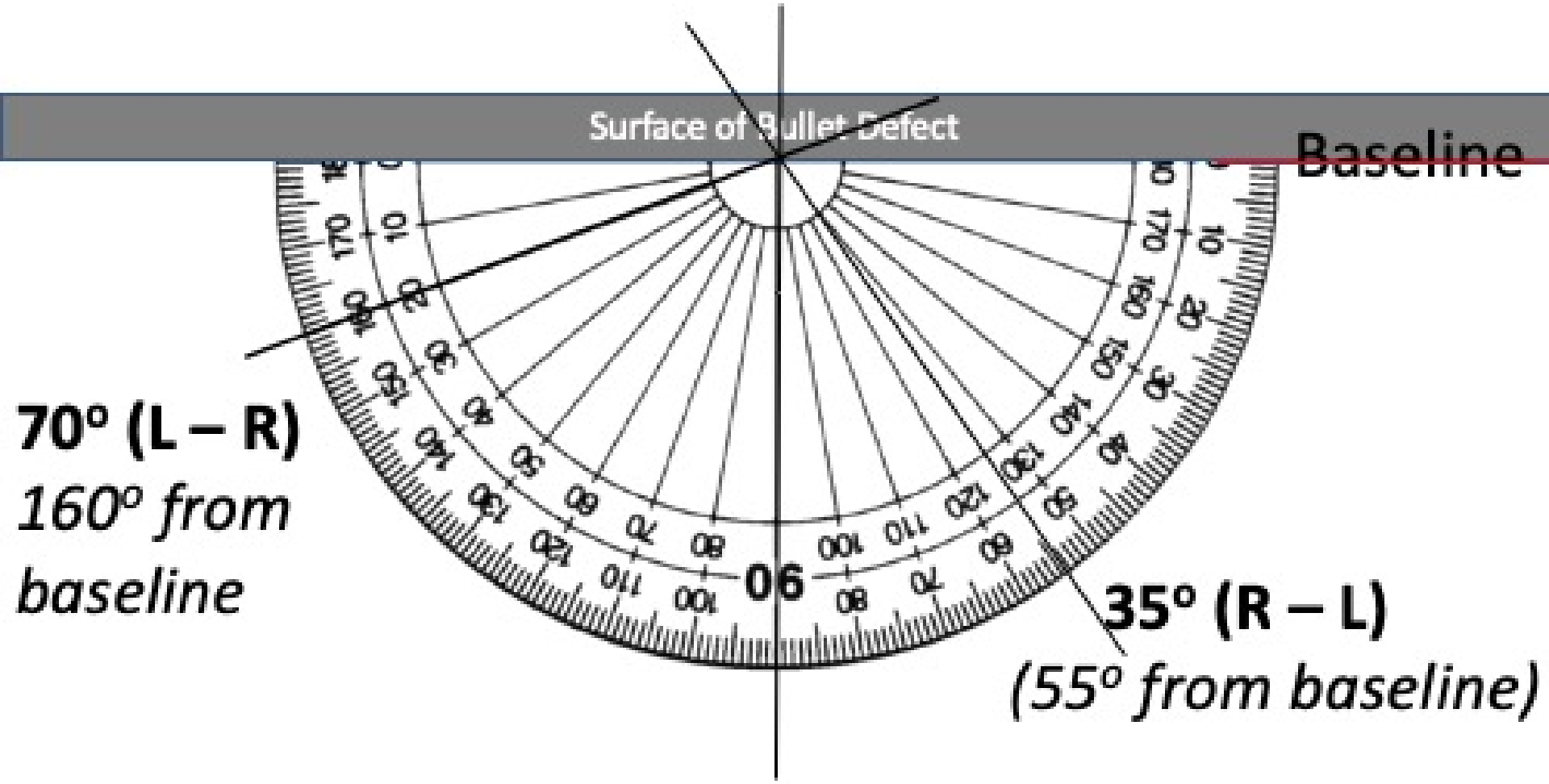
- Shallow angles, less than 10^{o}
- Proper documentation
  - Orthogonal views – scale in plane
  - Gamma angle noted
- Identifying the ellipse
  - Total length and/or ½ and double

Reading Azimuth Angles (Top View)

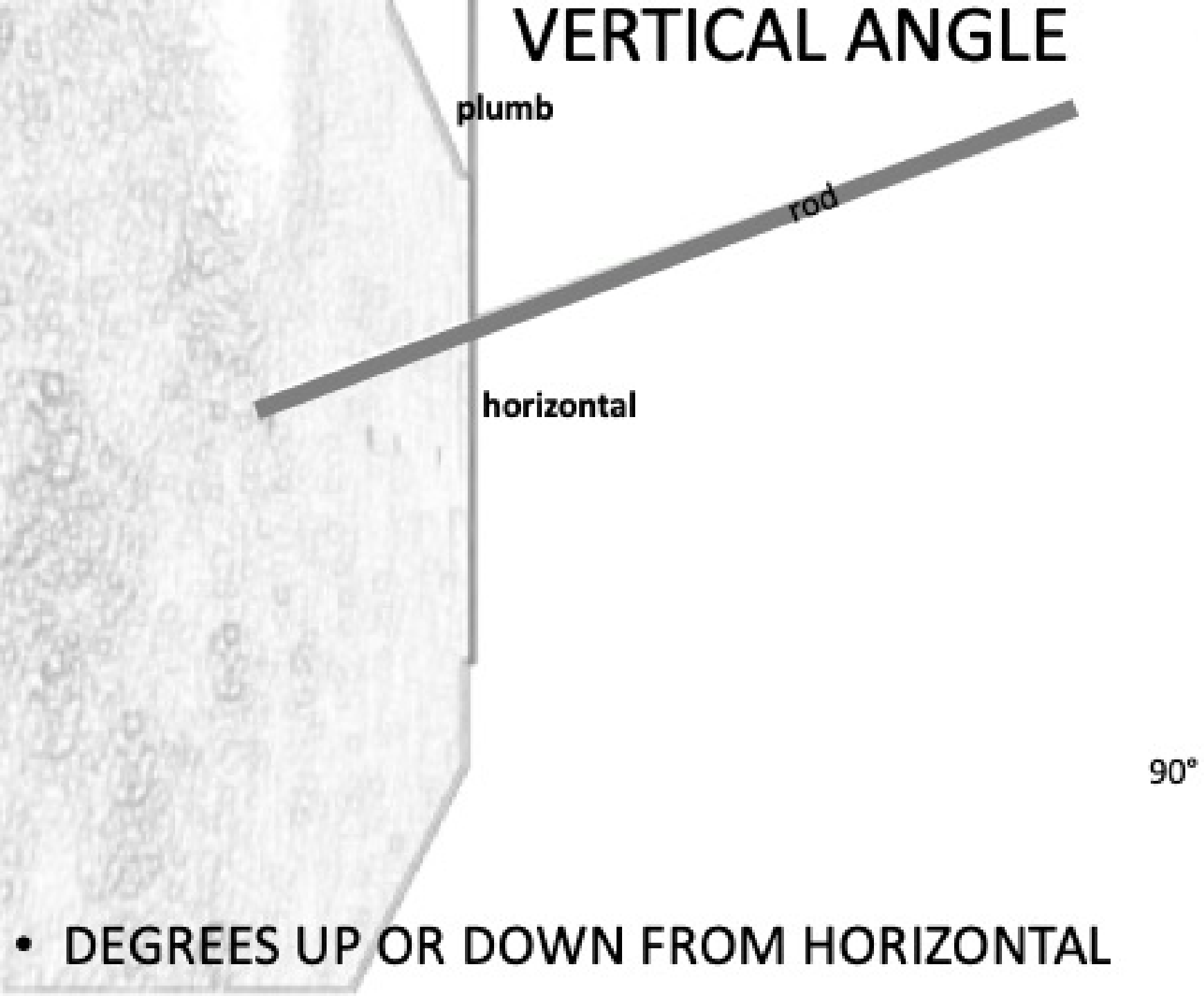


90 degrees=zero

Reading Azimuth Angles (Top View)

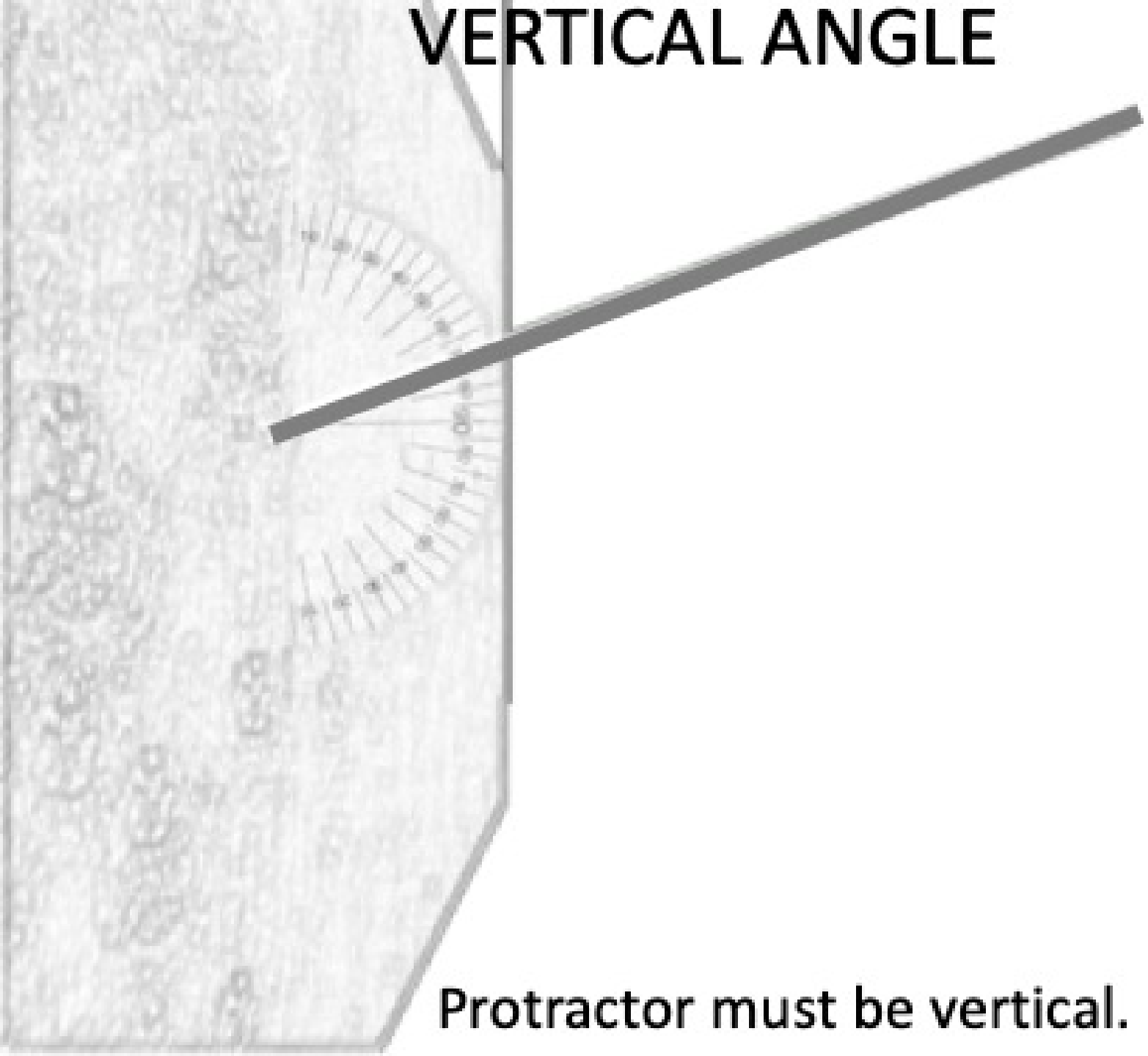


VERTICAL ANGLE



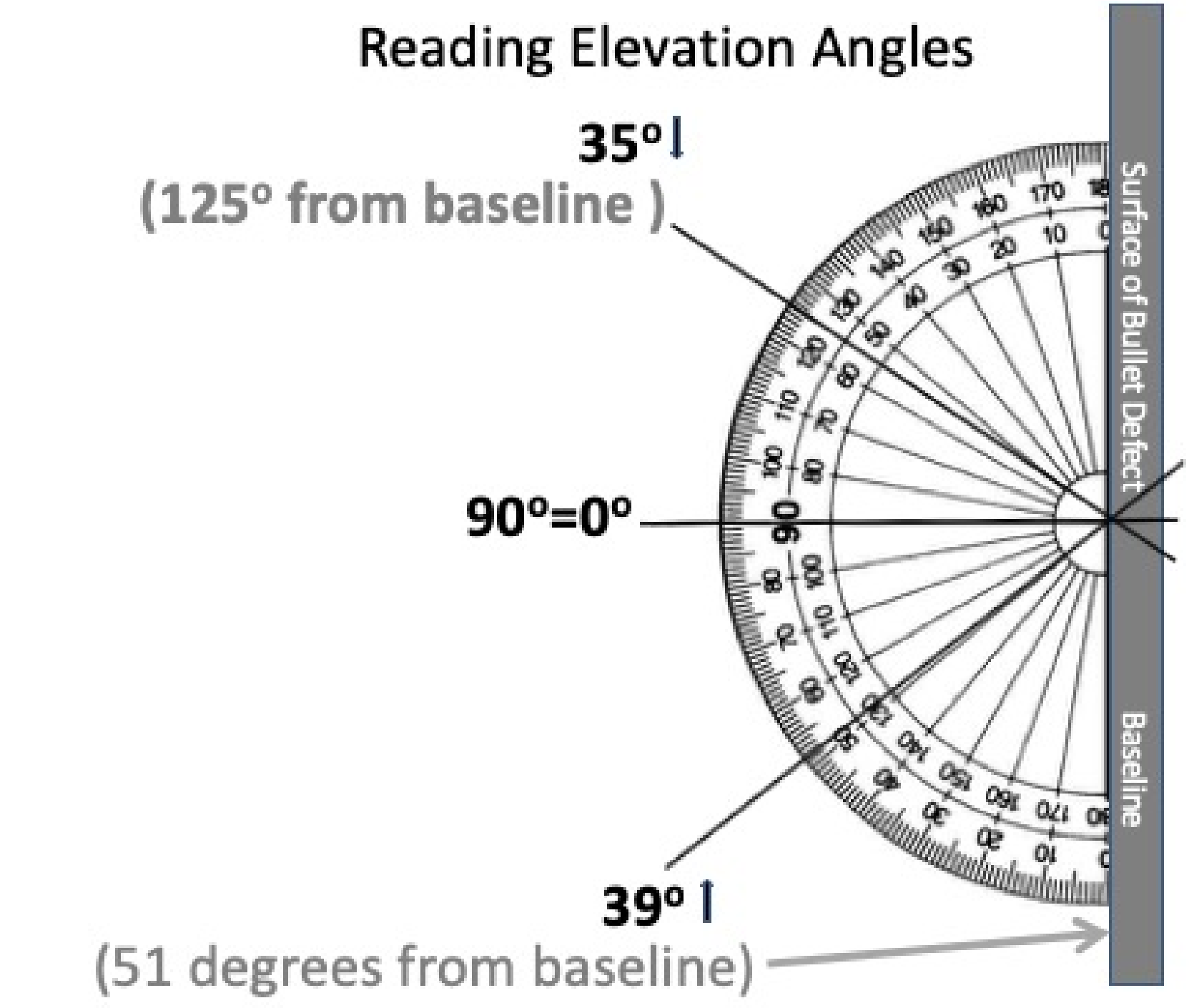
- DEGREES UP OR DOWN FROM HORIZONTAL

VERTICAL ANGLE



Protractor must be vertical.

Reading Elevation Angles



90° (perpendicular) = 0° (Both Elevation and Azimuth)

Try it….you might just like it!!

Practical Exercises

- #1 Practical Road AD
  - Trajectory analysis thru trigonometry
- #2 Mystery Shooting
  - Trajectory and ricochet analysis thru trigonometry
- #3 Death by Gravity
  - Trajectories outside the box