

**THE
LONG
RANGE
SHOOTING
HANDY
REFERENCE
GUIDE**



ILLUSTRATED

BY KARIN CHRISTENSEN

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TABLE OF CONTENTS

PART I THE BULLET IN FLIGHT

The Rifle Bore - Barrel Rifling - Twist rate - Rotational Speed of the Bullet •	page 5
Stability Factor •	page 6
Muzzle Velocity •	page 7
Bullet Meplat •	page 8
Bullet Ogive •	page 8
Tangent - Secant - Hybrid Ogives •	page 9
Bullet Center of Mass - Center of Pressure Angle of Attack •	page 10
Wind •	page 11
Crosswind •	page 12
Wind Direction •	page 13
Spin (Gyroscopic) Drift •	pages 14 and 15
Aerodynamic Jump •	pages 16 and 17
Magnus Effect •	page 17
Coriolis Effect •	page 18
Eötvös Effect •	page 19
Coriolis and Eötvös Effect Data •	page 20
Drag - Frontal Area - Dynamic Pressure •	page 21
Aerodynamics •	pages 22 and 23
Drag Coefficient •	page 24
Measuring Drag Coefficient	
Chronographs •	page 25
Time of Flight •	page 26
Doppler Radar •	page 27
Shock waves •	pages 28 and 29
Mach Numbers •	page 29
G1 and G7 standard bullets •	page 30
Drag Curves •	page 31
Additional G Models •	page 32
Drag Equation •	page 32
Gravity •	page 33
Adjusting Elevation •	page 34
Inclination Angles •	page 35
Air Density •	pages 35 and 36
Barometric Pressure •	page 36
Temperature •	page 37
Humidity •	page 37

TABLE OF CONTENTS

PART 2 AIMING THE BULLET

- Minute of Angle • page 38
- Mil Radians • page 39
- The Reticle (MOA and MIL) • pages 40 and 41
- Adjust for drop and drift
 - MOA turrets • page 42
 - MIL turrets • page 43
- Prepare a Range Card • page 44
- Moving Targets • page 45
- Handy Equations • page 46

PART 3 CHALLENGES

- Instructions • page 47
- Elevation Angles .308 caliber • pages 48 and 49
- Moving Targets .223 caliber • pages 50 and 51
- Differential Wind .50 caliber • pages 52 and 53
- Temperature Variations .338 caliber • pages 54 and 55
- Temperature Variations 300 Win Mag • pages 56 and 57
- Advanced Challenges 6.5 Creedmoor • pages 58 and 59

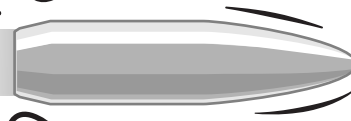
PART 4 END NOTES

- Right hand twist vs. Left hand twist • page 60
- 6.5mm vs .264 inch • page 60



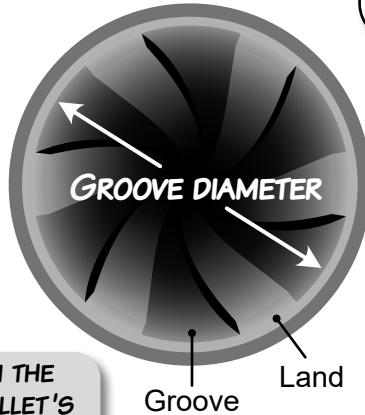
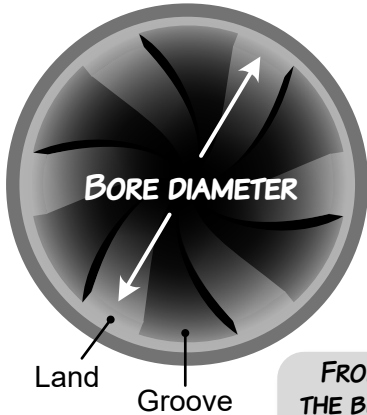
PART 1

THE BULLET IN FLIGHT

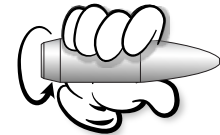


IN ORDER FOR A BULLET TO BE STABLE IN FLIGHT IT HAS TO BE SPINNING.

THE RIFLE BORE



FROM THE BULLET'S POINT OF VIEW



Right hand spin

Rifling is a grooved, spiral pattern machined into the surface of the bore which produces the bullet spin.

1 IN 10 TWIST (1:10)

10 inches of barrel length

TWIST RATE



Bullet makes one full revolution in 10 inches of barrel length

NOT TO SCALE

1 IN 7 TWIST (1:7)

7 inches of barrel length

FOR THE SAME BORE DIAMETER: A 1:7 TWIST RATE IS FASTER THAN A 1:10 TWIST RATE



Bullet makes one full revolution in 7 inches of barrel length

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ROTATIONAL SPEED OF THE BULLET

$$\text{Rotation (revolutions per second)} = \frac{12}{\text{Twist rate}} \times \text{Muzzle velocity}$$

$$\text{Rotation per second} \times 60 = \text{Rotations per minute (RPM)}$$

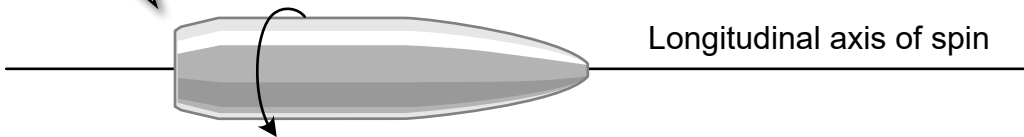
FASTER

Muzzle velocity = 2650 ft/sec 1:10 twist = 190,800 RPM 1:7 twist = 272,580 RPM

STABILITY FACTOR

Estimates stability of a bullet in flight

IN ORDER FOR A BULLET TO BE STABLE IN FLIGHT IT HAS TO BE SPINNING.



THE MILLER FORMULA

Stability factor (Sg)

Bullet mass in grains (m)

$$Sg = \frac{30 \times m}{t^2 d^3 l (1 + l^2)}$$

Twist in calibers per turn (t)

Bullet diameter in inches (d)

Bullet length in calibers (l)

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

Twist in calibers per turn (t) = divide twist rate in inches (T) by caliber diameter in inches (d)

IF A BULLET HAS A SG OF LESS THAN 1.0 IT WILL BE UNSTABLE AND WILL TUMBLE. SG OF 1.4 OR GREATER IS IDEAL.

Other variables such as bullet weight, aerodynamic properties and atmospheric conditions can also affect stability

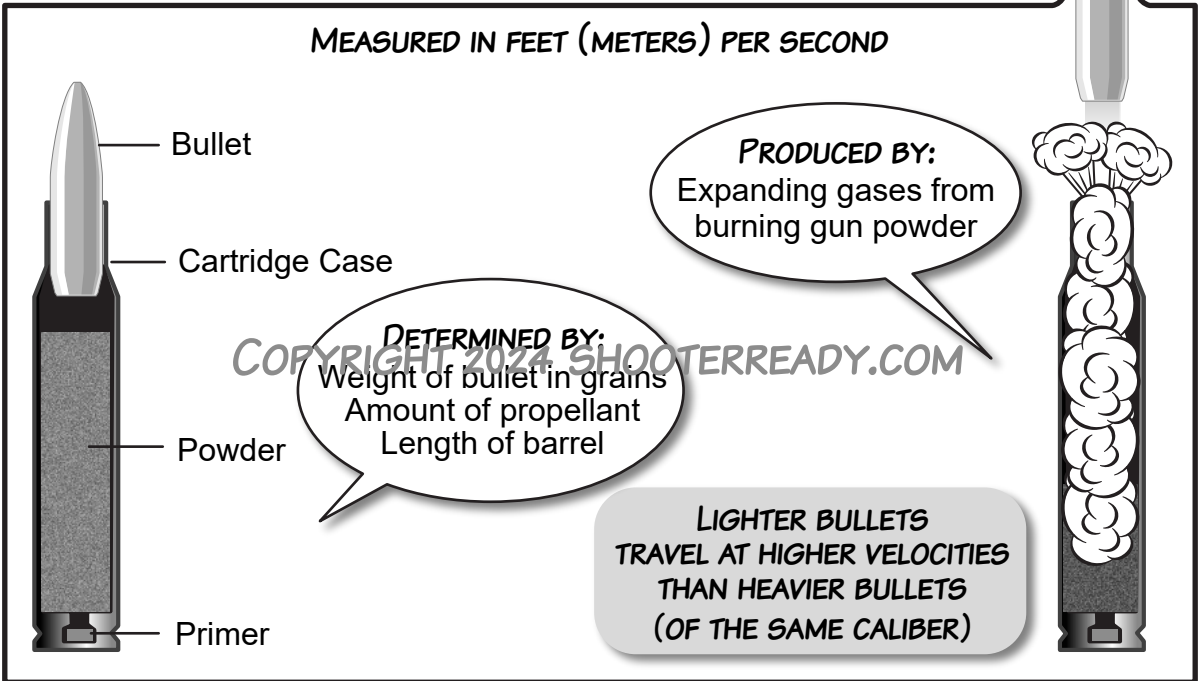
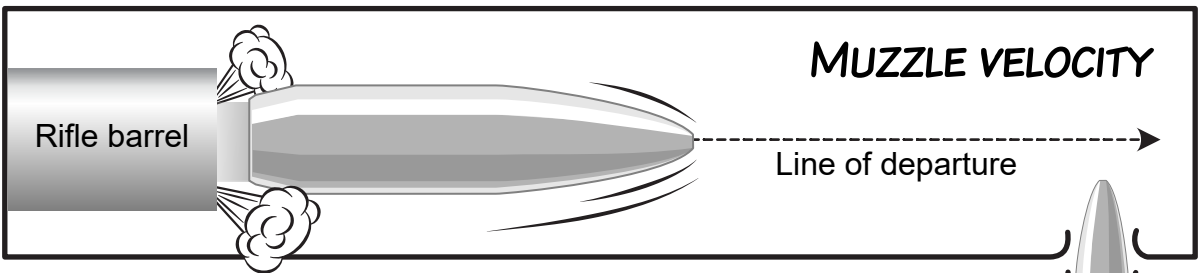
A BULLET BECOMES MORE GYROSCOPICALLY STABLE AS IT FLIES DOWN-RANGE. SPIN RATE DECAYS SLOWER THAN THE VELOCITY WHICH FAVORABLY AFFECTS THE AERODYNAMIC PROPERTIES OF THE BULLET.

Range increases →

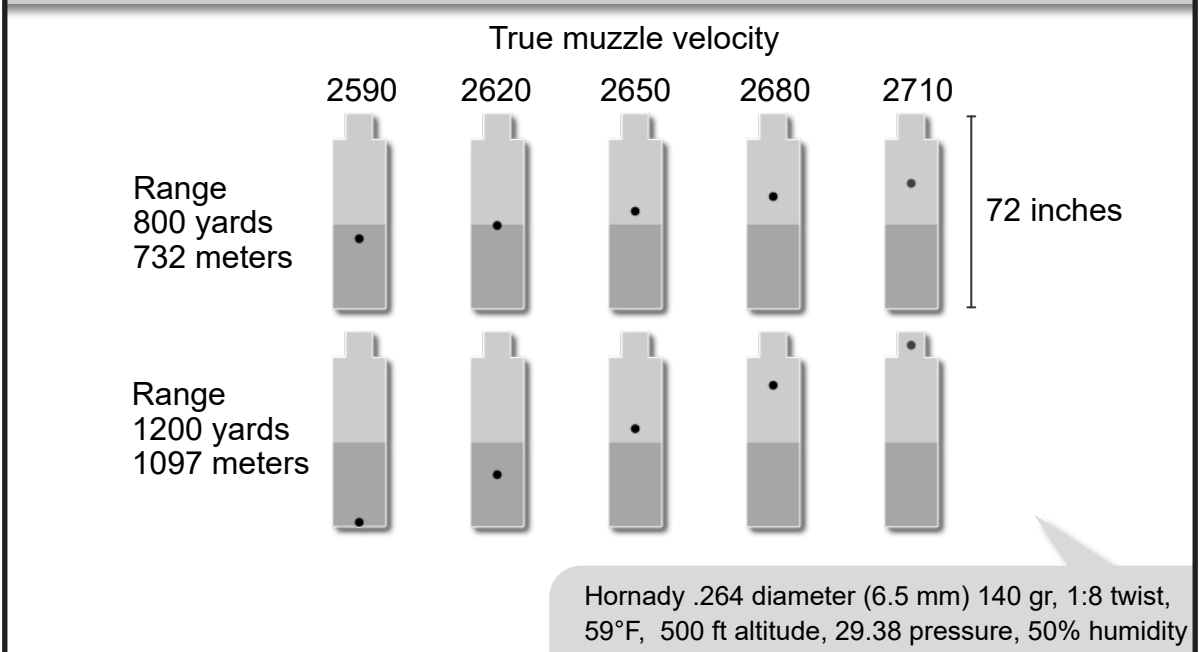
Yards	muzzle	100	200	300	400	500	600	700	800	900	1000	
Meters	muzzle	91	183	274	366	457	549	640	732	823	914	
Sg		1.74	1.87	2.0	2.13	2.27	2.44	2.62	2.79	3.01	3.25	3.62

→ Stability factor (Sg) increases

Hornady .264 diameter (6.5 mm) 140 gr, 1:8 twist, 57°F, 500 ft altitude, 29.38 pressure, 50% humidity



IF THE RIFLE IS ZEROED WITH A MUZZLE VELOCITY OF 2650 FT/SEC A SMALL CHANGE IN TRUE MUZZLE VELOCITY WILL AFFECT THE TRAJECTORY.



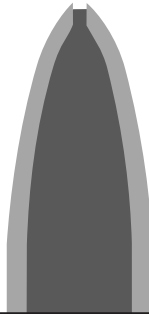
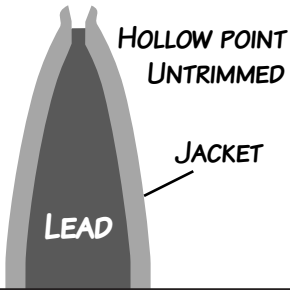
THE MEPLAT

Tip of the bullet

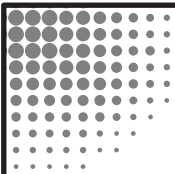
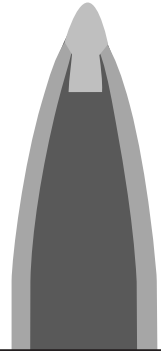
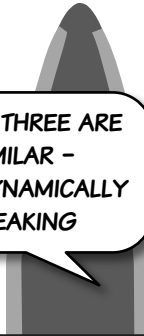
HOLLOW POINT TRIMMED

SOFT POINT

POLYMER TIP



THESE THREE ARE SIMILAR - AERODYNAMICALLY SPEAKING



Circular arc

OGIVE

The radius of a circular arc

A CALIBER IS DEFINED AS THE INTERNAL GROOVE DIAMETER OF A GUN BARREL OR THE DIAMETER OF A PROJECTILE IN HUNDREDTHS OF AN INCH.

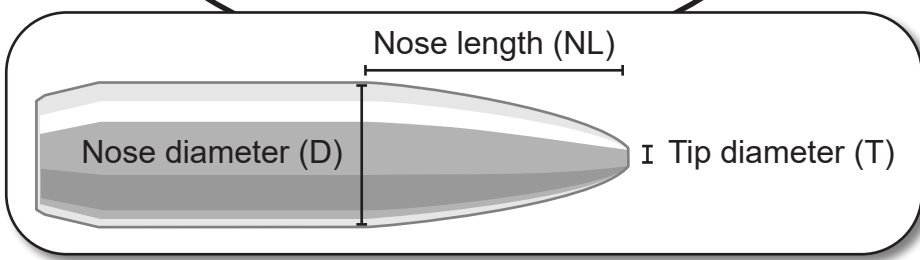
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OGIVE VALUE STATED IN CALIBERS

$$\text{Ogive caliber} = \frac{\text{Ogive radius in inches}}{\text{Caliber in inches}}$$

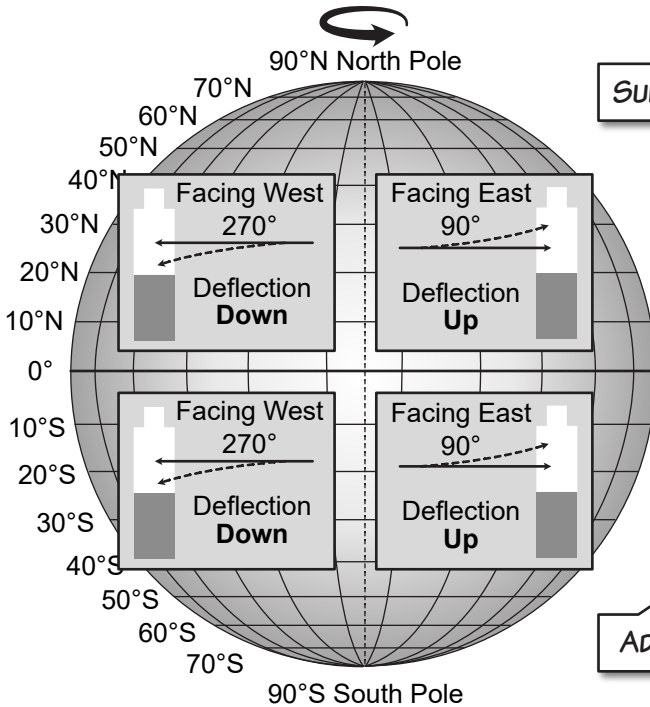
CALCULATE RADIUS LENGTH (RL) IN INCHES

$$RL = \frac{NL \times NL}{(D - T)} + \frac{(D - T)}{4}$$



EÖTVÖS EFFECT

VERTICAL EFFECT RELATED TO THE AZIMUTH OF FIRE (HEADING) RELATIVE TO TRUE NORTH.



The bullet traveling **westward** is deflected **downward**.

EFFECT IS GREATEST NEAR THE EQUATOR.

The bullet traveling **eastward** is deflected **upward**.

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THE EQUATION

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EÖTVÖS EFFECT

$$f = 1 - \frac{2 \times \Omega \times MV}{g} \times (\cos(\text{Lat}) \times \sin(\text{Az}))$$

f gravity correction factor

MV muzzle velocity

Ω rotation of the earth in rad/sec

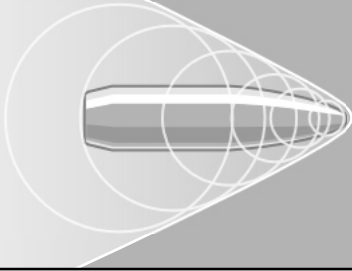
g acceleration of gravity (32.2 ft/s²)

Lat Latitude (+north, - south)

Az azimuth of fire (heading)

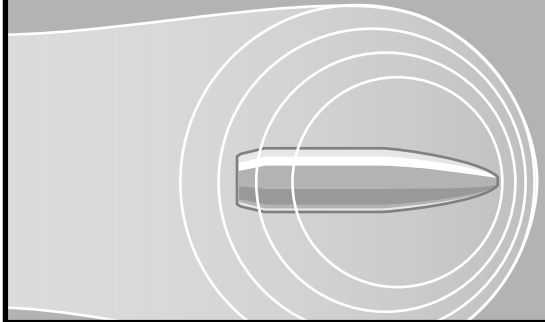
Equation from Litz, Applied Ballistics for Long-range Shooting Second edition, 2011

AT SUPERSONIC SPEED



The shape of the ogive is the more important factor in reducing drag.
Boat-tail shape not as important.

AT SUBSONIC SPEED



The boat-tail design is more important at reducing drag.
Ogive shape not as important.

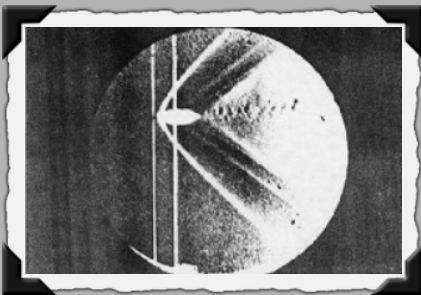
MACH NUMBER

Mach is a ratio of the speed of the object to the speed of sound.

Speed of sound is dependent on air density.

Air density is dependent on altitude, temperature and humidity.

Temperature is the most important factor.



The term 'Mach' was named in honor of the scientist Ernst Mach (1838 - 1916) who photographed a bullet flying at supersonic speed which he presented in a paper in 1887*.

**Photographische Fixirung der durch Projectile in der Luft eingeleiteten Vorgänge. Von E. Mach und P. Salcher*

THE SPEED OF SOUND

In dry air at 0°C (32°F)
331.2 meters per second
1,087 feet per second

In dry air at 20°C (68°F)
343 meters per second
1,125 feet per second

MACH NUMBER

$$\frac{\text{Speed of object}}{\text{Speed of sound}}$$

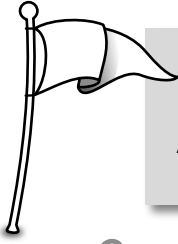
If the speed of the object equals the speed of sound
Mach = 1

In dry air at 0°C (32°F)
Mach 1 = 1087 feet per second
Mach 2 = 2174 feet per second
Mach 3 = 3261 feet per second

In dry air at 20°C (68°F)
Mach 1 = 1125 feet per second
Mach 2 = 2250 feet per second
Mach 3 = 3375 feet per second

ADJUST FOR DROP AND DRIFT

With a MIL Turret Scope



In the following example:
At 555 yards there is a 75" drop
A 5 mph 9:00 wind gives 13" drift to the right
Calculated with exterior ballistic software

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At 555 yards 1 mil = 19.98 inches

$$(\text{Inches of drift} \times \text{mph}) \div (3.6 \times (\text{Range (yards)} \times 0.01)) = \text{MIL}$$

Elevation 75" drop at 555 yards = 3.8 MIL

$$(75 \text{ inches} \div 19.98) = 3.75 (3.8) \text{ MIL}$$

Wind 13" drift at 555 yards = 0.7 MIL

$$(13 \text{ inches} \div 19.98) = 0.65 (0.7) \text{ MIL}$$

ELEVATION KNOB



Elevation 38 clicks up

3.8 MIL

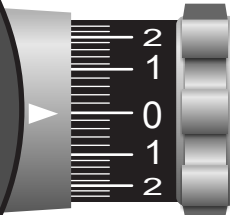


MIL turrets
0.1 MIL clicks

Wind 7 clicks to the left

0.7 MIL

WIND KNOB



WIND FROM THE LEFT WILL MOVE
THE BULLET TO THE RIGHT.
ADJUSTMENT IS TO THE LEFT.

RESOURCES AND ANSWERS FOR .308 CALIBER

Range Card MOA turrets

Range (yards)	Elevation MOA	Wind MOA	Inches drift 1 mph wind
200	1.8	0.14	0.3
250	3.1	0.15	0.4
300	4.5	0.19	0.6
350	6.0	0.22	0.8
400	7.6	0.26	1.1
450	9.3	0.30	1.3
500	11.0	0.34	1.8
550	12.9	0.38	2.2
600	14.9	0.43	2.7
650	16.9	0.47	3.2
700	19.1	0.51	3.7
750	21.4	0.56	4.4
800	23.8	0.61	5.1
850	26.4	0.65	5.8
900	29.1	0.71	6.7
950	31.9	0.75	7.5
1000	34.9	0.81	8.5

Range Card MIL turrets

Range (yards)	Elevation MIL	Wind MIL	Inches drift 1 mph wind
200	0.5	0.0	0.3
250	0.9	0.0	0.4
300	1.3	0.1	0.6
350	1.7	0.1	0.8
400	2.2	0.1	1.1
450	2.7	0.1	1.3
500	3.2	0.1	1.8
550	3.8	0.1	2.2
600	4.3	0.1	2.7
650	4.9	0.1	3.2
700	5.6	0.2	3.7
750	6.2	0.2	4.4
800	6.9	0.2	5.1
850	7.7	0.2	5.8
900	8.5	0.2	6.7
950	19.3	0.2	7.5
1000	10.2	0.3	8.5

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BULLET

.308 caliber
 175 grain Sierra Matchking bullet
 muzzle velocity 2635 ft/sec
 1.8 inch sight height
 Sierra Infinity 6 Exterior Ballistic Software

RANGE CARD CONDITIONS

3280 feet altitude
 65° F
 55% humidity
 Standard (corrected) barometric pressure 29.53
 100 yard zero

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ANSWERS

4

Range 600 yards (Target 2.22 MIL)
 Elevation 11 MOA center (7.2 to 14.7 MOA range)
 Wind 1.7 MOA Right
 Range from center (2.5 Left to 4.7 Right)

3

Range 650 yards (Target 7.05 MOA)
 Elevation 16.7 MOA center (13.2 to 20.22 MOA range)
 Wind 0.9 MOA Right
 Range from center (2.5 Left to 4.5 Right)

2

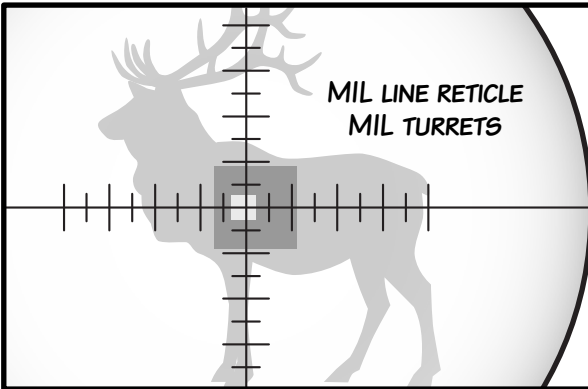
Range 800 yards (Target 1.67 MIL)
 Elevation 5.7 MIL center (4.8 to 6.4 MIL range)
 Wind 0.7 MIL Right
 Range from center (0.5 Left to 1.0 Right)

1

Range 740 yards (Target 1.8 MIL)
 Elevation 6.0 MIL center (5.1 to 6.9 MIL range)
 Wind 0.6 MIL Right
 Range from center (0.6 Left to 1.2 right)

INCLINATION ANGLES

.308 CALIBER

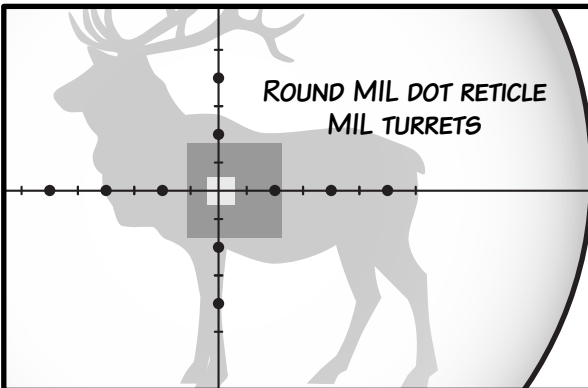


Range conditions **1**
Wind 3:00 4 mph
Inclination angle 10° uphill

Altitude 3280', Temp 57°F,
Humidity 49%, Baro 29.53

Elevation MIL _____

Windage MIL _____

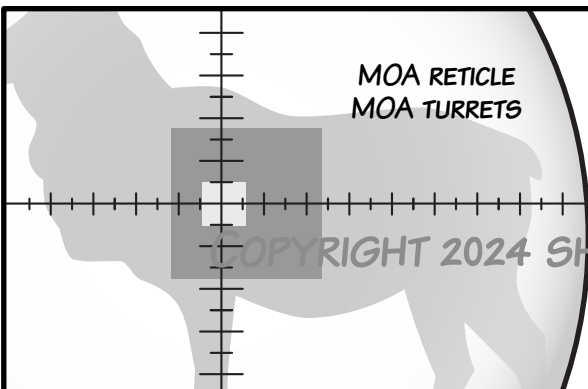


Range conditions **2**
Wind 3:00 4 mph
Inclination angle 35° uphill

Altitude 3280', Temp 57°F,
Humidity 49%, Baro 29.53

Elevation MIL _____

Windage MIL _____

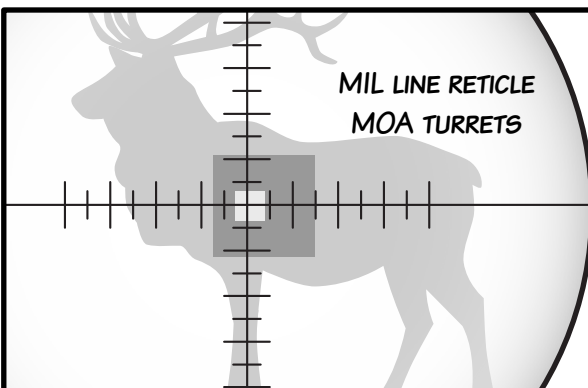


Range conditions **3**
Wind 3:00 2 mph
Inclination angle 10° downhill

Altitude 3280', Temp 57°F,
Humidity 49%, Baro 29.53

Elevation MIL _____

Windage MIL _____



Range conditions **4**
Wind 3:00 4 mph
Inclination angle 40° downhill

Altitude 3280', Temp 57°F,
Humidity 49%, Baro 29.53

Elevation MIL _____

Windage MIL _____