THE LONG RANGE SHOOTING HANDY REFERENCE GUIDE

ILLUSTRATED

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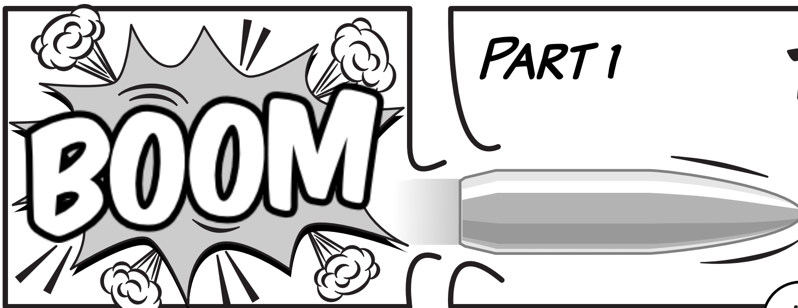
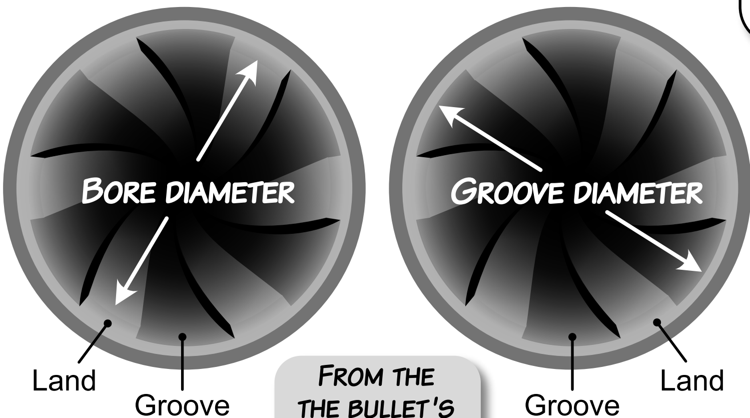


Part 1

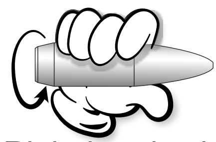
The Bullet in Flight

In order for a bullet to be stable in flight it has to be spinning.

The Rifle Bore



From the 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.

Twist Rate

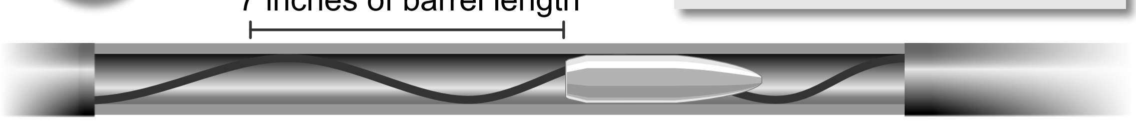
1 in 10 twist (1:10)
10 inches of barrel length

Bullet makes one full revolution in 10 inches of barrel length

Not to scale

For the same bore diameter: A 1:7 twist rate is faster than a 1:10 twist rate

1 in 7 twist (1:7)
7 inches of barrel length



Bullet makes one full revolution in 7 inches of barrel length

Rotational speed of the bullet

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

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

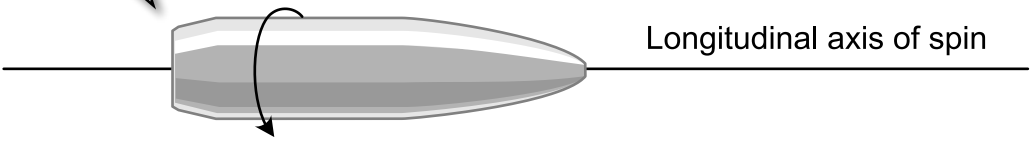
Faster

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

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

- Stability factor (Sg)
- Bullet mass in grains (m)
- Twist in calibers per turn (t)
- Bullet diameter in inches (d)
- Bullet length in calibers (l)

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

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.

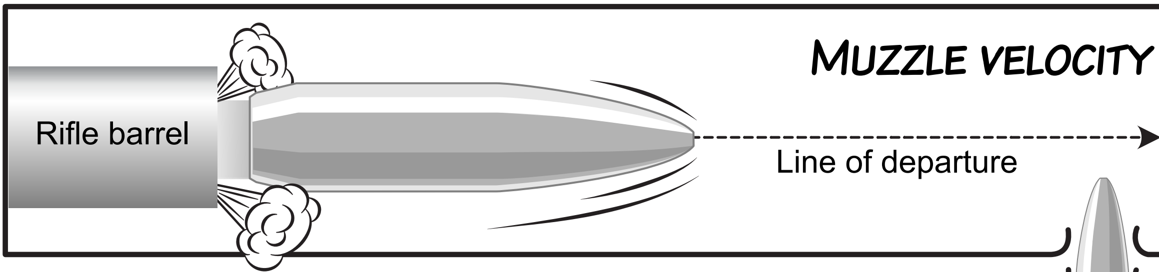
Range increases →

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

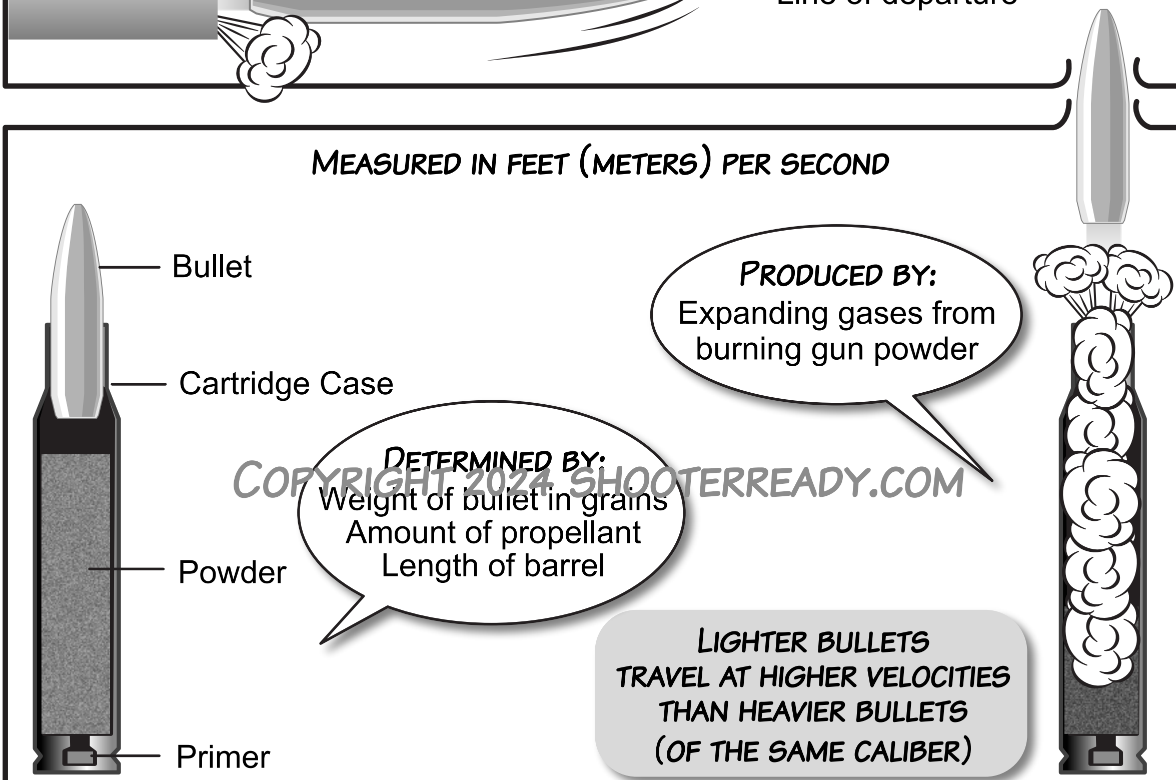
Stability factor (Sg) increases →

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

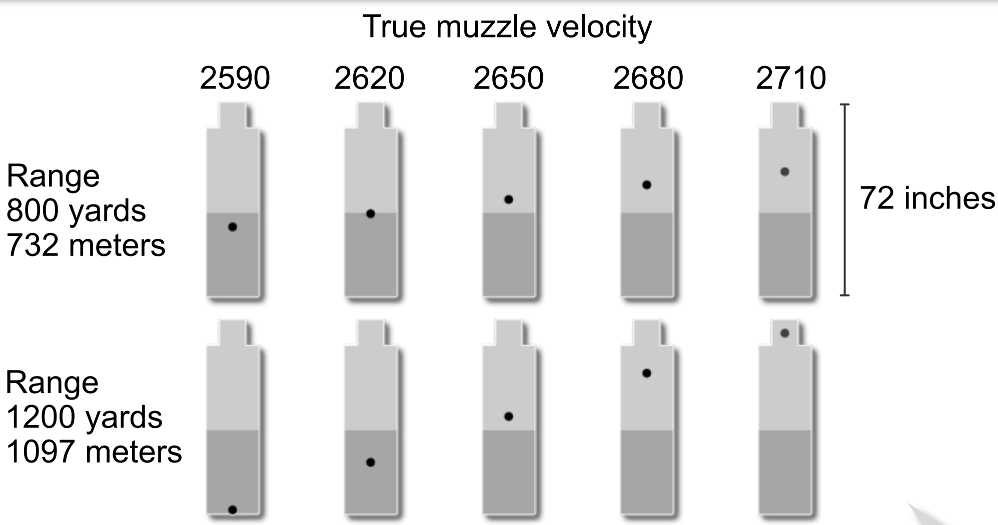
Muzzle velocity



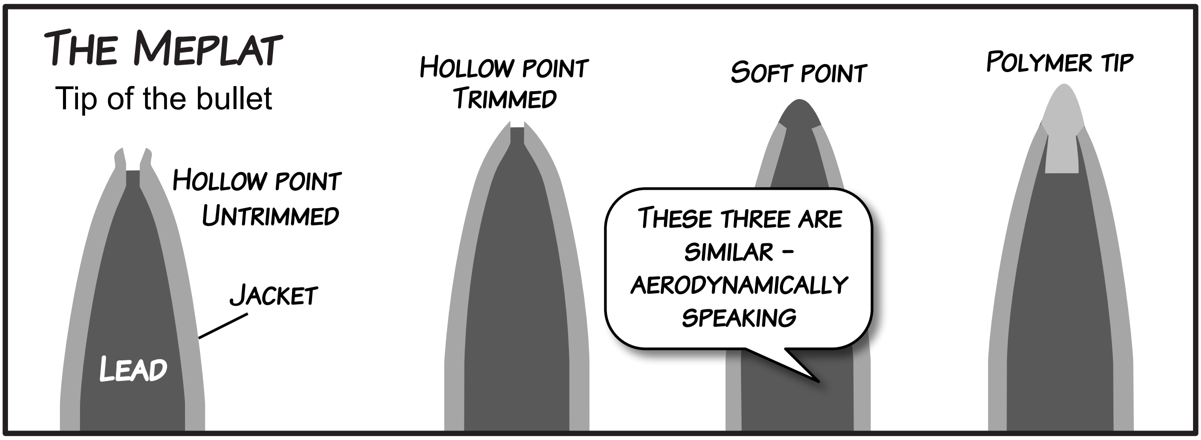
Measured in feet (meters) per second

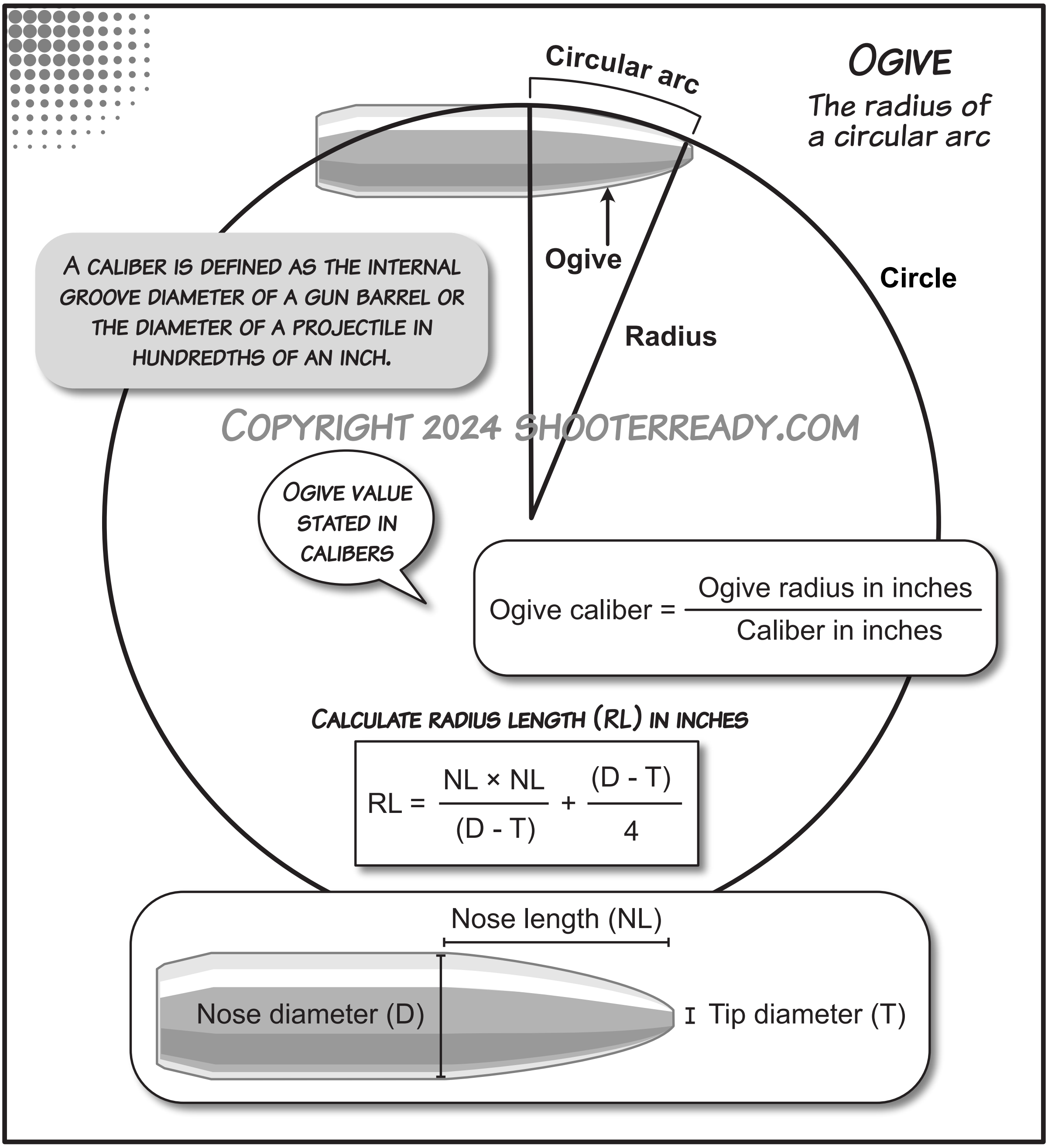


If the rifle is zeroed with a muzzle velocity of 2650 ft/sec a small change in true muzzle velocity will affect the trajectory.



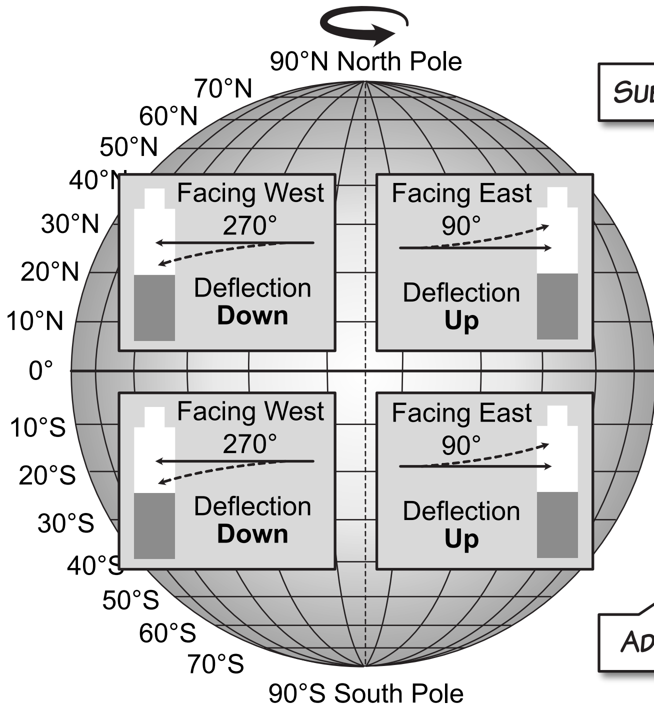
Hornady .264 diameter (6.5 mm) 140 gr, 1:8 twist, 59°F, 500 ft altitude, 29.38 pressure, 50% humidity


THE MEPLAT
Tip of the bullet
HOLLOW POINT UNTRIMMED
JACKET
LEAD
HOLLOW POINT TRIMMED
SOFT POINT
POLYMER TIP
THESE THREE ARE SIMILAR – AERODYNAMICALLY SPEAKING


OGIVE
The radius of a circular arc
Circular arc
Ogive
Radius
Circle
A CALIBER IS DEFINED AS THE INTERNAL GROOVE DIAMETER OF A GUN BARREL OR THE DIAMETER OF A PROJECTILE IN HUNDREDTHS OF AN INCH.
COPYRIGHT 2024 SHOOTERREADY.COM
OGIVE VALUE STATED IN CALIBERS
Ogive caliber = Ogive radius in inches / Caliber in inches
CALCULATE RADIUS LENGTH (RL) IN INCHES
$RL = \frac{NL \times NL}{(D - T)} + \frac{(D - T)}{4}$
Nose length (NL)
Nose diameter (D)
Tip diameter (T)

EÖTVÖS EFFECT

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



SUBTRACT FROM ELEVATION

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

← EFFECT IS GREATEST NEAR THE EQUATOR.

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

ADD TO ELEVATION

THE EQUATION

EÖTVÖS EFFECT

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

f gravity correction factor

MV muzzle velocity

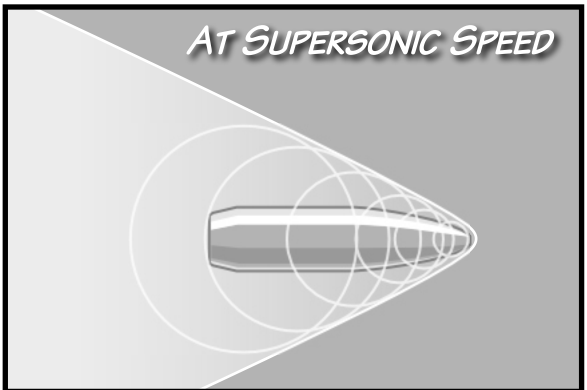
Ω rotation of the earth in rad/sec

g acceleration of gravity (32.2 ft/s^2)

Lat Latitude (+north, - south)

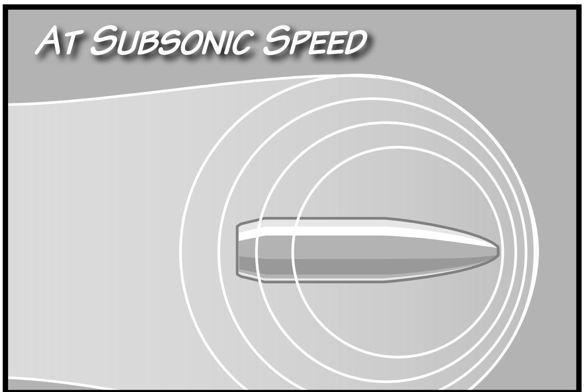
Az azimuth of fire (heading)

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



The shape of the ogive is the more important factor in reducing drag.

Boat-tail shape not as important.



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 Speed of Sound

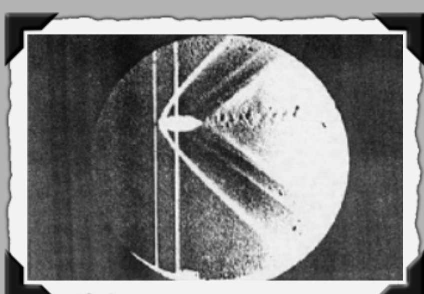
In dry air at 0°C (32°F)
331.2 meters per second
1,087 feet per second

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



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.*

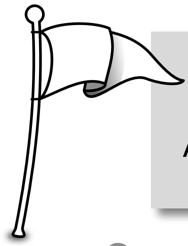
**Photographisobe Fixirung der durch Projectile in der Luft eingeleiteten Vorgänge. Von E. Mach und P. Salcher*

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

At 555 yards 1 mil = 19.98 inches

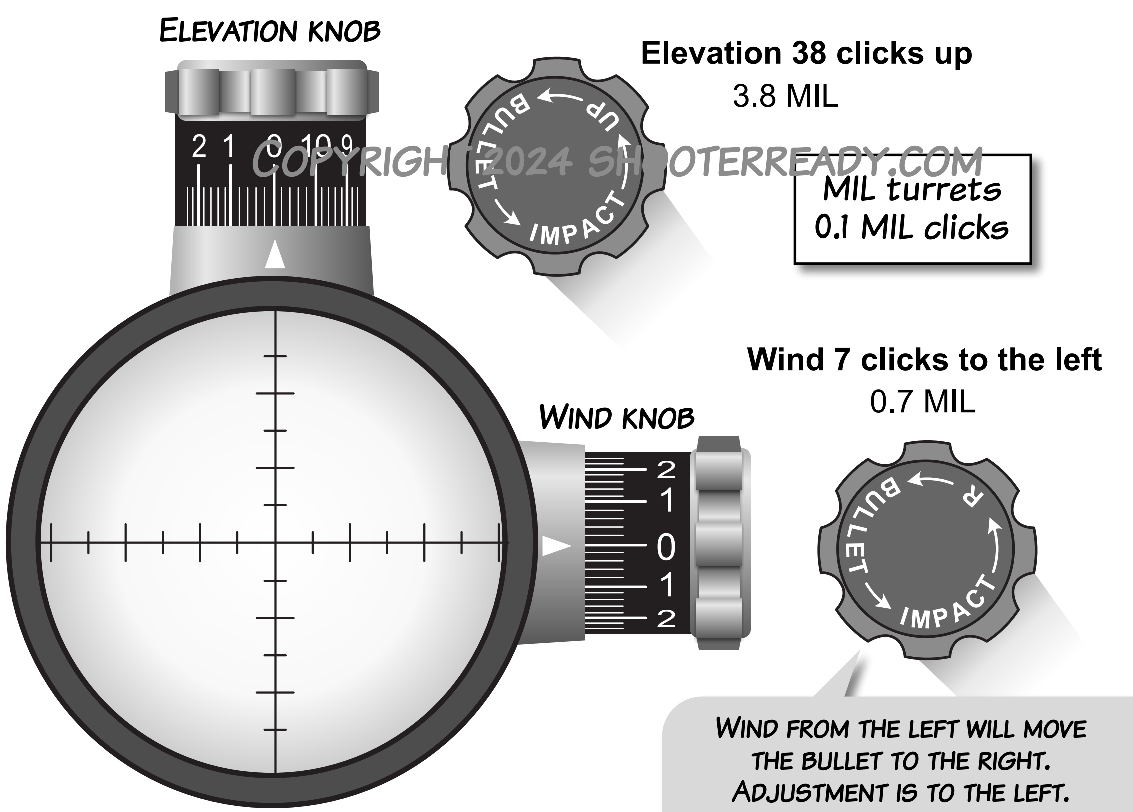
(Inches of drift × mph) ÷ (3.6 × (Range (yards) × 0.01)) = MIL

Elevation 75" drop at 555 yards = 3.8 MIL

(75 inches ÷ 19.98) = 3.75 (3.8) MIL

Wind 13" drift at 555 yards = 0.7 MIL

(13 inches ÷ 19.98) = 0.65 (0.7) MIL



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

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

Answers

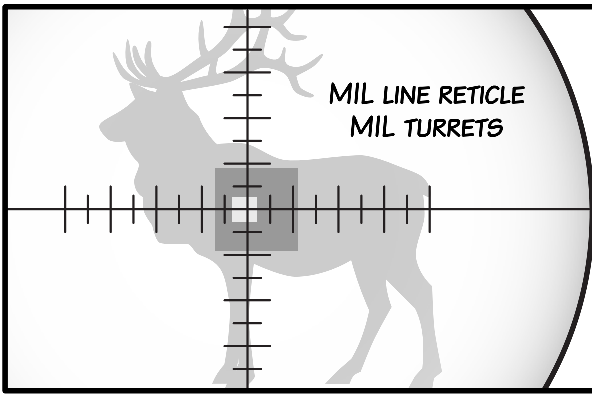
1
Range 740 yards (Target 1.8 MIL)
Elevation 6.0 MIL center
(5.1 to 6.9 MIL range)
Wind 0.6 MIL Right
Range from center (0.6 Left to 1.2 right)

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)

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)

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)

INCLINATION ANGLES .308 CALIBER



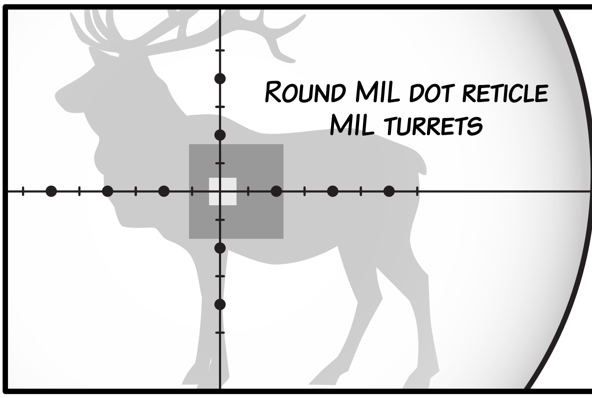
Range conditions
Wind 3:00 4 mph
Inclination angle 10° uphill

1

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

Elevation MIL ________

Windage MIL ________



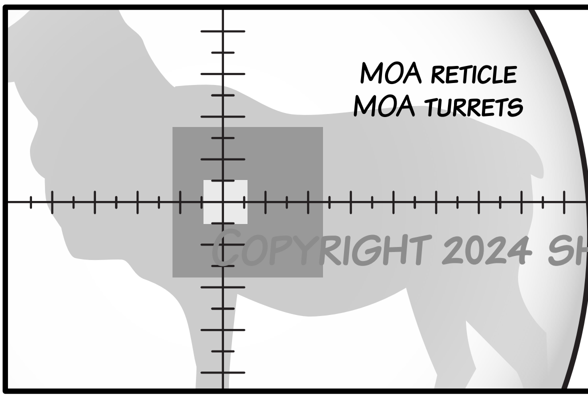
Range conditions
Wind 3:00 4 mph
Inclination angle 35° uphill

2

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

Elevation MIL ________

Windage MIL ________



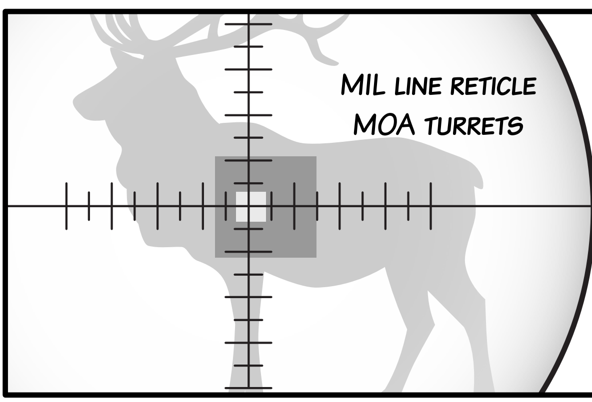
Range conditions
Wind 3:00 2 mph
Inclination angle 10° downhill

3

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

Elevation MIL ________

Windage MIL ________



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

4

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

Elevation MIL ________

Windage MIL ________