The Study of Gunsmithing



Sonoran Desert Institute

MODULE NUMBER 7

Reloading



2013. All rights reserved. Except for use in a review, no portion of this book may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form without the express written permission of Sonoran Desert Institute. The scanning, uploading, and distribution of this book by the Internet or any other means without the permission of Sonoran Desert Institute is illegal and punishable by law. Please respect Sonoran Desert Institute's rights and don not participate in any form of electronic piracy or copyrighted material.

Sonoran Desert Institute does not assume any responsibility for the use or misuse of information contained in this book.

Special contributor: Lee Shaver, Gunsmith

MODULE NUMBER 7

Reloading

2197 Basic Ballistics

2198 Development of the Modern Cartridge

2199 Advanced Ballistics

2200 Reloading and Custom Ammo-Making

2201 Bullet Swaging and Casting

2202 Shotshell Components and Reloading

2162 Scope Mounting Lab (#)

(#) Indicates point in your program at which additional lesson materials will be sent as you complete and return the lesson exams for grading.

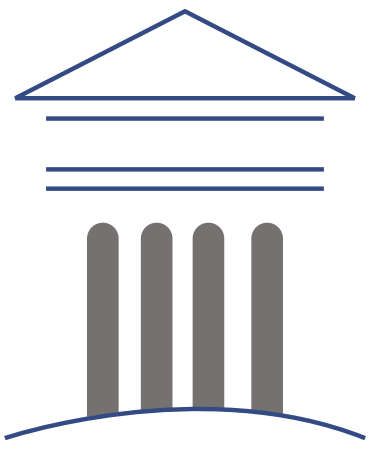
Sonoran Desert Institute



You agree (a) to indemnify and hold harmless Trade Training Company LLC dba Sonoran Desert Institute and their affiliates and their respective officers, directors, employees, advisors, and agents (each, an "indemnified person") from and against any and all losses, claims, damages and liabilities to which any such indemnified person may become subject to arising out of or in connection with this Enrollment Agreement, the Facilities, the use of the proceeds thereof, the Transactions or any related transaction or any claim, litigation, investigation or proceeding relating to any of the foregoing, regardless of whether any indemnified person is a party thereto, and to reimburse each indemnified person upon demand for any reasonable legal or other expenses incurred in connection with investigating or defending any of the foregoing, provided that the foregoing indemnity will not, as to any indemnified person, apply to losses, claims, damages, liabilities or related expenses to the extent they are found by a final, non-appealable judgment of a court to arise from the willful misconduct or gross negligence of such indemnified person, and (b) to reimburse Trade Training Company LC, and their affiliates on demand for all out-of-pocket expenses (including due diligence expenses, syndication expenses, consultant's fees and expenses, travel expenses and reasonable fees, charges and disbursements of counsel) incurred in connection with the Facilities and any related documentation or the administration, amendment,modification or waiver thereof.

Basic Ballistics
Lesson: 2197

OBJECTIVES	3
INTRODUCTION	3
BASIC BALLISTICS	4
Trajectory	5
Wind Drift	6
Breech Pressure	7
Energy	7
Killing Power	8
Recoil	8
Velocity	8
Effect Of Barrel Length on Velocity	9
Accuracy	9
Self-Test Questions	9
GUNNING CALCULATIONS	10
Calculating Bullet Drop	11
Self-Test Questions	13
BALLISTIC GLOSSARY	14
Self-Test Questions	16
ANSWERS TO SELF-TEST QUESTIONS	17
LESSON QUESTIONS	18





Objectives

After completing this lesson, you should

1. Have a basic understanding of the difference between interior and exterior ballistics and how they relate to gunsmithing.
2. Know what trajectory is and how it is determined.
3. Be able to define pressure.
4. Know the difference in trajectory between light and heavy bullets.

Introduction

Rifles and cartridges are useful only when used together. The end product of this combination is a bullet spinning through the air toward a target.

All the time, care, effort, and money expended in designing a fine rifle and cartridge culminate in the one purpose of a small, cylindrical, pointed object boring through the atmosphere at tremendous speed.

It is essential that you understand how bullets behave in flight, and what can be expected from rifles and bullets of different calibers. The science of projectiles in flight is known as *ballistics*, and basic ballistics is what this lesson is all about.

Basic Ballistics

More and more sports enthusiasts are becoming interested in the subject of ballistics and its application to modern guns and ammunition.

The Greeks called it "ballein," meaning to *throw*. An early Roman war machine, which hurled large objects, was called the "ballista." From these ancient words, the modern term *ballistics* was derived to indicate the science of moving projectiles.

As the study of ballistics progressed, the field of ballistics was broken into two entirely different phases: interior and exterior ballistics. *Interior ballistics* pertain to performance inside the gun. *Exterior ballistics* deal with what happens to the projectile in its flight from gun muzzle to target and is of more interest to hunters and shooters because of its application to their problems. Interior ballistics are more the concern and interest of the ammunition manufacturer but are of importance when studying complete bullet performance. The gunsmith should be familiar with both.

The realm of interior ballistics extends inside the barrel from the *breech* (rear) to the *muzzle* (open end). The enlarged rear portion of the barrel accommodates the cartridge and is known as the chamber. Just in front of the chamber is a short conical section known as the *throat*. The area from the throat to the muzzle is called the bore of the gun.

The bore is either smooth or rifled. The shotgun is a smoothbore weapon. A rifled bore is so named because of the parallel grooves, from 2 to as many as 12 or more, which are cut spirally up the barrel to the muzzle.

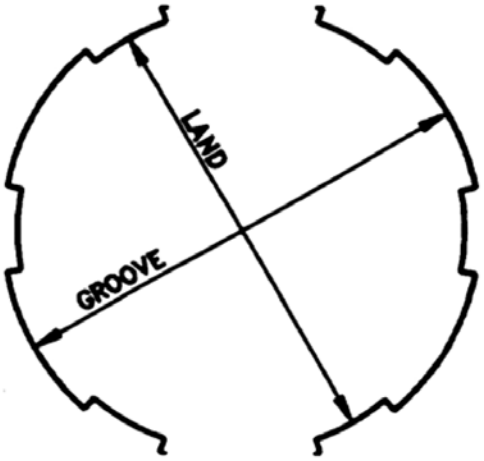


***Figure 1**: Rifling, consisting of lands and grooves, spins the fired bullet during its flight from the muzzle to the target. The spinning stabilizes the bullet in flight.*

These grooves are .002" to .006" in depth and are called *rifling*. The raised portion in the bore, between two adjacent grooves is called a *land* (Figure 1). Gun calibers are commonly designated by *bore diameter*, which is the inside diameter of the barrel before the grooves are cut. *Groove diameter*, although seldom used, is measured from the bottom of one groove to the bottom of an opposite groove.

Rifling is necessary to make the bullet travel in a direct path. The longer the bullet in relation to its diameter, the faster it has to be spun. The rate of spin, or twist, in rifling varies from as many as one turn every $6\,^1/_3$" to as few as one turn every 60", depending on the velocity, diameter, and weight of the bullet. Because there is some leeway in the amount of spin a bullet needs to maintain its gyratory stability, different bullet weights may be fired successfully and accurately from the same gun.

Cartridge cases are controlled and gauged carefully during manufacturing to assure proper functioning in all standard chambers. A case must not only chamber easily and quickly, it must withstand a tremendous expanding pressure during firing and still be extracted with ease and certainty. To compensate for this, a metallic cartridge is slightly smaller in diameter than the chamber of the gun. Under pressure of the powder gas, obduration takes place, in which the case expands against the chamber wall, making a tight seal and preventing gas from escaping to the rear. At the same time, the cartridge case head is solidly supported in the breech mechanism to prevent separation of case and head from the inside pressure. As the bullet leaves the muzzle, the pressure in the bore and chamber drops and the cartridge case shrinks enough to allow extraction from the chamber.

Each cartridge is made of four parts: case, bullet, powder, and primer, as shown in Figure 2. Case type, whether rimmed, rimless, straight, or bottleneck, is a matter of choice. Each is designed for a specific powder charge to permit the shortest, straightest, and minimum required action or breech mechanism. Proper design results in proper firing.

In a centerfire cartridge, the primer is located in a small well, or depression, in the center of the case head. It is a small cup containing the priming charge and an anvil. The priming charge is crushed against the anvil when the primer is struck and dented by the firing pin. Hot gases pass through a flash hole, which extends from the bottom of the primer well to the inside of the case, and into the powder charge for ignition.

A rimfire cartridge carries its priming mixture in the flat rim at the base of the shell. This rim also serves to locate the cartridge properly in the chamber and as a means of extracting the cartridge case after firing.

One of the major problems in interior ballistics is uniform ignition of the powder by the primer. Only by close control of ignition can uniform pressure and muzzle velocities be maintained. All modern American primers are engineered precisely to perform efficiently with modern smokeless powder.



Figure 2: The four part of a cartridge are the primer, bullet, case and powder.

Routine ballistic and control tests conducted by various ammunition manufacturers include pressure velocity measurements; barrel time (the time it takes a bullet to emerge from the muzzle after the firing pin falls); primer sensitivity tests; chamber gauging tests; and push and pull tests on the crimp of the bullet in the case.

Only by producing ammunition to exacting interior ballistic specifications is it possible to produce ammunition with uniform exterior ballistic performance.

The field of exterior ballistics, with its problems of air resistance, trajectory, wind drift, accuracy, and remaining energy, covers the study of the bullet after it leaves the muzzle of the gun.

TRAJECTORY

The pattern and curved path of a bullet in flight is known as trajectory. Several forces act upon a bullet to change its flight to the target.

Let's see what really happens after a bullet leaves the barrel. First, the bullet must be given a spin to keep it steady, like a spinning top, so it will stay on target. This is accomplished by the spiral lands of the rifling gripping the bullet jacket. Long bullets require a more rapid spin to stabilize than short bullets. For this reason the twist of the rifling varies according to caliber of the rifle, usually from one turn in 10 inches to one turn in 14 inches. In most cases, a compromise is adopted that is satisfactory for the different weight bullets that are available in most calibers. If both the bullet base and the muzzle of the rifle are perfectly square, the bullet will leave without tipping, which is detrimental to good accuracy. But, it is immediately affected by two main forces — gravity and air resistance.

To better understand the effect of gravity and air resistance, let's assume that we have two rifles, one shooting a 150-grain bullet, the other a 180-grain bullet. (A grain is a unit of measure equal to 1/7000 of a pound.) Both are .30 caliber and both leave the muzzle at 3,000 feet per second (fps) velocity. Let's further assume that both are on a platform with their muzzles exactly 16.08' above the ground, and the axis of each barrel is exactly parallel to the ground, which in turn is perfectly level for a considerable distance away from the platform (Figure 3). Now, suppose both rifles are fired simultaneously, and that we let a bullet fall from our hand at exactly the same height, and at the exact same instant the two bullets leave the muzzle of the two rifles. What happens?

All three bullets will strike the ground at the same instant. The dropped bullet will land on the ground close to the platform; the 150-grain bullet at 2,186'; the 180-grain bullet at

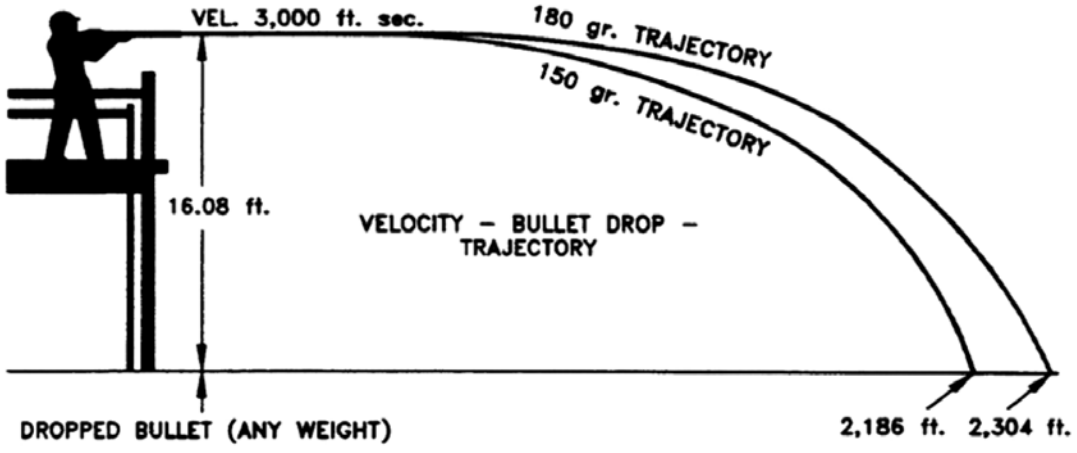


Figure 3: A dropped object falls 16.08' in one second. All fired bullets approximate this. The higher the velocity, the flatter the trajectory. But heavier bullets sustain their velocity longer than lighter ones.

2,304 feet. Although both fired bullets left the guns at a rate of 3,000 fps, neither bullet will achieve that distance. Air resistance will slow down their flight, so neither can go that far in the one second that gravity will give them to fall 16.08 feet. The 150-grain bullet will be affected to the same extent as the 180-grain by the heavy hand of gravity, but it will be affected by air resistance somewhat more than the 180-grain, since the 150-grain has more surface exposed in relation to its weight.

To get back to the platform, if we could actually see the flight of these two bullets, we would notice that they were following an ever-increasing curve until they hit the ground, as shown in Figure 3, on page 5. That's because the bullet is both losing velocity and dropping at an ever-increasing rate. Obviously, if we want the bullet to go further, we have to point the barrel upward and project the bullet higher into the air, giving it more time to fall.

Even though the rifle is parallel to the ground, the bullet is rising slightly above a line projected forward from the rear and front sights (the line of sight). Figure 4 shows that in relation to the axis of the bore, the bullet begins to fall the moment it leaves the muzzle, just as it did from the hypothetical 16' platform. The curved path of a bullet's flight is called its trajectory. The higher the velocity, the less curve there will be over a given distance. Because the trajectory is flatter, a rifle with a higher velocity than another is called flatter shooting.

However, you do not get up on 16' platforms when you shoot. You stand, or perhaps lie, prone on the ground aiming at a target about 100 or perhaps 200 yards away. How can you be sure to hit you target? Ignoring the human element, if you have a fairly high velocity rifle, say 2,400 fps, you are certain to make a hit if your rifle is zeroed-in—sighted to hit where you aim at a measured 150 yards. If the target is only 100 yards away, your hit will be a little high; at 150 yards, on the button; at 200 yards, a little low.

It follows that rifles with higher velocities and flatter trajectories can be zeroed-in at 200 yards with good results at 250 to 300 yards. On the other hand, lower velocity rifles would be limited to a 100-yard range, and either the rear sight should be raised or a higher aim taken on a target beyond 150 yards.

WIND DRIFT

Bullet flight is affected by wind drift. A crosswind, particularly one at right angles to the bullet's flight, may push the bullet off target a noticeable amount at long ranges. At short ranges, with high-velocity cartridges, the effect is small and need not be taken into account. However, wind drift will have little or no effect on a bullet that is traveling directly upwind or downwind.

In a crosswind of 10 miles an hour, a .22-caliber Long Rifle bullet, with a muzzle velocity of 1,335 fps, will be blown downwind 5" at 100 yards, and 17" at 200 yards. An identical wind will blow a 30-06, 180-grain soft-point bullet off its path 2½" at 300 yards. A 30 mph wind will have three times this effect.

For all practical purposes, at normal shooting ranges up to 300 yards, even in fairly heavy winds, only a small allowance is necessary for wind drift. At 400 or 500 yards, and up to 1,000 yards, ranges ordinarily shot by target shooters, the wind drift must be carefully estimated. Wind estimating requires long practice and a great amount of skill and judgment on the part of the shooter because the wind is rarely constant.

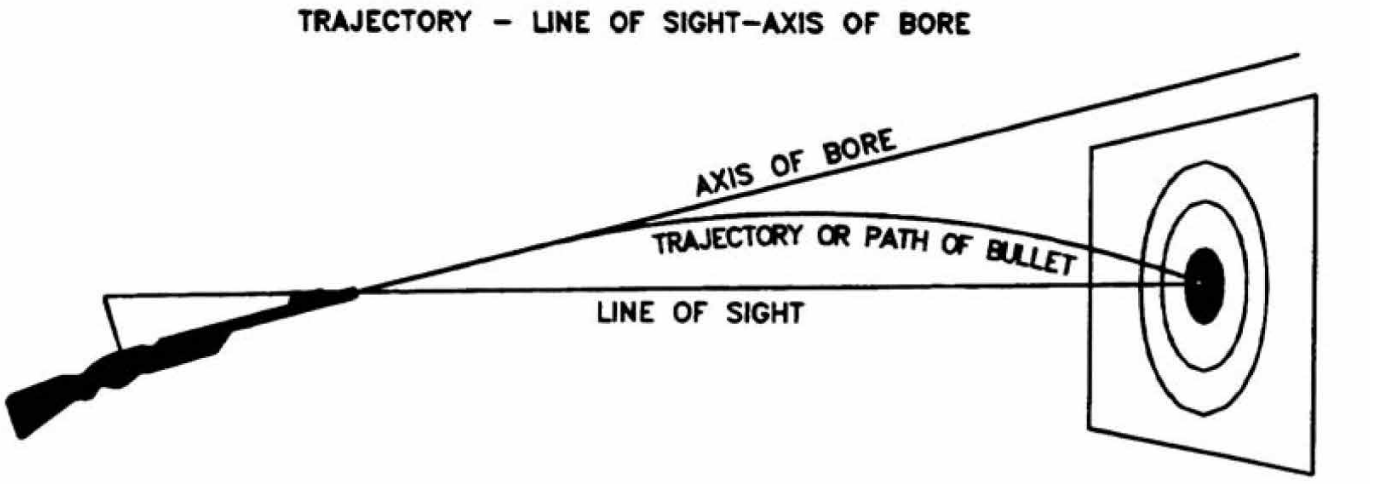


Figure 4: *For the bullet to go further, the barrel must be pointed upwards so that the bullet is projected higher into the air, giving it more time to fall.*

Table of Wind Allowances							
22 Long Rifle High Velocity . . . Deflection of Bullet in Inches and Minutes							
Distance	Wind Velocity (Miles per Hour)	1, 5, 7, 11 o'clock Wind Direction		2, 4, 8, 10 o'clock Wind Direction		3 and 9 o'clock Wind Direction	
		Inches	Min.	Inches	Min.	Inches	Min.
50 yards	5	0.33	0.66	0.57	1.14	0.66	1.32
	10	0.67	1.33	1.15	2.31	1.33	2.66
	15	1.00	1.98	1.72	3.45	1.99	3.98
	20	1.34	2.66	2.30	4.61	2.66	5.32
100 yards	5	1.25	1.25	2.17	2.17	2.50	2.50
	10	2.50	2.50	4.33	4.33	5.00	5.00
	15	3.75	3.75	6.50	6.50	7.50	7.50
	20	5.00	5.00	8.67	8.67	10.00	10.00
200 yards	5	4.28	2.14	7.42	3.71	8.56	4.28
	10	8.56	4.28	14.84	7.42	17.12	8.56
	15	12.84	6.42	22.26	11.13	25.68	12.84
	20	17.12	8.56	29.69	14.84	32.24	17.12

BREECH PRESSURE

Questions are frequently asked concerning the amount of breech pressure, or chamber pressure, produced by a specific cartridge. This question cannot be answered with a single number of pounds per square inch since the pressure is never constant from the time the powder starts burning until the bullet leaves the barrel. For example, the maximum or peak pressure can be expressed as 50,000 pounds per square inch (psi), but this number is entirely misleading except to the experienced ballistician.

First, this peak pressure is an instantaneous peak, so its effects are completely different than the constant or slowly changing pressures of normal experience. Only an engineer experienced in interpreting the effect of this rapidly changing pressure can apply these peak pressure measurements reliably. Second, there are such a large number of conditions which affect this measurement that a simple number of pounds per square inch is meaningless. Even an experienced ballistician cannot interpret such measurements unless the complete conditions are known.

While it becomes obvious that pressure results are almost meaningless to the layperson, they are of great importance to both gun and ammunition manufacturers.

Gun manufacturers correlate their gun designs with actual tests to make sure proper safety factors are built into their guns while ammunition manufacturers control pressures within corresponding limits.

ENERGY

Normally, energy is expressed in foot/pounds. By knowing the weight of the bullet and its velocity at the desired range, energy is easily computed. Here is the formula:

$$\frac{\text{Velocity} \times \text{Velocity} \times \text{Bullet Weight}}{450{,}240} = \text{Energy at desired range}$$

$$\frac{\text{fps} \times \text{fps} \times \text{grains}}{450{,}240} = \text{ft./lbs.}$$

The variables are velocity in feet per second and bullet weight in grains. The constant denominator is 450,250.

Bullet energy is of great interest to the hunter, as well as the manufacturer, because of its close relationship to killing power, which in turn is important to prevent the crippling of game. Killing power is not based on energy alone. The rate and method of application of energy to the animal is equally important. For example, a full metal case bullet may pass completely through an animal and travel on for some distance; a soft-point bullet of the same velocity will expand and deliver its entire energy within the body of the animal.

KILLING POWER

A clean kill on all types of game is the desire of a true sportsperson. The hunter desires to prevent the suffering and mutilation of his prey. No one yardstick among present published information — which includes velocity, energy, bullet types and weights, and diameter — is available which can be used to measure killing power, although the above data has some influence in determining effective killing power. All other factors being equal, it is generally accepted that within the limits of proper cartridge use, a comparison of energies is a fair comparison of killing power.

When one cartridge has a large, heavy bullet that travels at a slow speed and another has a light bullet that travels at high velocity, energy alone is not enough to make a fair comparison. For that reason, even though muzzle energies may be approximately equal, a lightweight, high-velocity bullet will tend to create a superficial wound on large game, whereas a slower and larger bullet will penetrate deeper and produce better killing power. Therefore, it is important that the proper bullet be selected.

RECOIL

Any gun that is fired has some recoil. This is true of the lightest rifles as well as the heaviest big-game guns. Bullet weight and velocity, the weight of the powder charge, and the weight of the gun affect the recoil. A lighter gun will have a heavier recoil than a heavier gun with the same cartridge.

Recoil begins the instant the bullet starts moving down the barrel. But because a rifle fires with tremendous speed, the delayed action of recoil does not affect the shooter's aim. When the bullet and powder gases have left the muzzle, the rear of the rifle has received all the recoil velocity, although it has only moved a fraction of an inch at this time. However, the gun continues to move backward against the shooter's shoulder until all recoil energy has been absorbed by the shoulder.

Ammunition manufacturers are limited as to the bullet weight and velocity that can be built into a cartridge because of a shooter's choice of gun weight and ability to withstand recoil. Increasing either bullet weight or velocity or decreasing gun weight will increase recoil, and vice versa.

VELOCITY

The forward speed of a bullet, usually specified in feet per second, is its *velocity*.

Perhaps the most interesting of all topics pertaining to exterior ballistics is velocity. The faster a bullet covers the distance from gun to target, the less it drops and the flatter its trajectory. Shooters and manufacturers search for high velocity because a flat trajectory minimizes errors in range estimation and results in surer hits at longer ranges. The need for high velocity is particularly apparent in long-range shooting.

Instantaneous muzzle velocity of any bullet cannot be measured accurately by any laboratory equipment. However, new scientific equipment, particularly the counter chronograph and photoelectric screen, make it possible to measure velocities with great accuracy over ranges as short as six feet. Loss of velocity over these short ranges is small and, thus, muzzle velocity is closely computed.

The customary method of measuring bullet velocity is to time the bullet as it passes over a specific distance. By dividing this distance by the measured time, the average number of feet per second the bullet travels can be computed. Remember, this is the average velocity over the range on which the bullet was timed. By plotting velocities over a series of ranges, a curve can be established to estimate muzzle velocity.

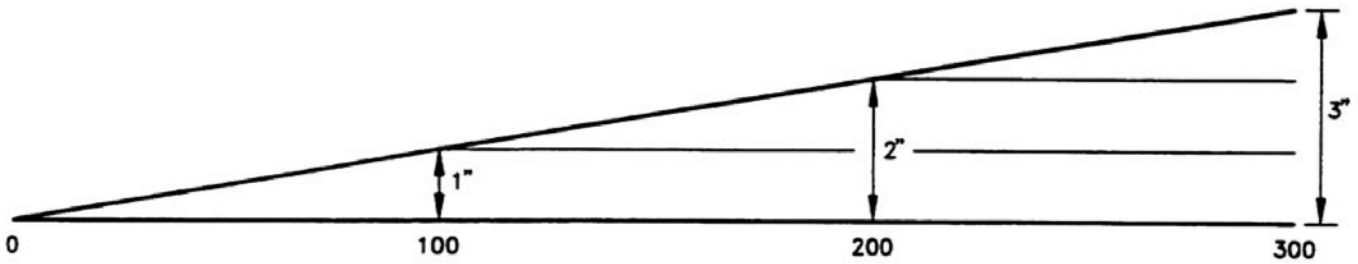


***Figure 5**: This diagram illustrates the effect of sight adjustment regarding range. The base line is calibrated to 300 yards with the angular line representing one minute of angle of sight adjustment.*

A high-velocity, light- or medium-weight bullet packs a lot of energy and killing power. But to prevent its breaking on impact and creating a superficial wound, it must be very carefully and specially made. Such modern high-velocity calibers as the .257 Roberts, .270 Winchester, .30-06 Springfield, .308 Winchester, and .300 Winchester Magnum have bullets which develop the full potential of the high-velocity weapon.

EFFECT OF BARREL LENGTH ON VELOCITY

With the old black powder loads, long barrels were used to develop full velocity from the powder charge. But today, modern smokeless powders at higher pressures develop high velocity in shorter barrels. Because extremely short barrels cause some loss of velocity and excessive muzzle blast, they should be avoided.

Certain standard-length barrels, depending upon caliber, are used to measure velocities. Conditions vary widely with different cartridges and with the same cartridges in different guns. It is impossible to set an exact figure for changes in velocity per inch of barrel length above or below standard. The correction may vary from 5 to as much as 25 fps per inch. A change of 25 fps per inch of barrel, above or below standard, will be approximately correct for rifles; 6-10' is acceptable for shotguns.

ACCURACY

No gun will put all its bullets through exactly the same hole on the target. Instead, the bullets striking the target form a pattern known as a *group*. The size of a group is measured by the distance between the centers of the two shots that are farthest apart. Accuracy, therefore, is the measurement of this group.

A *minute of angle* is the term used in measuring bullet dispersion and is approximately 1" at 100 yards. This is proportional to 2" at 200 yards, 3" at 300 yards, and so on, as shown in Figure 5. An ordinary sporting rifle is considered accurate for hunting purposes if it will shoot into three minutes of angle.

Many special target rifles and cartridges and many hunting cartridges, on the average, will shoot more accurately than the figures mentioned previously. Some of the records which have been established with modern target equipment and ammunition are truly surprising.

SELF-TEST QUESTIONS

Please check your answers on page 17.

1. **The pattern and curved path of a bullet in flight is known as _____ .**
2. **What causes a bullet to travel in a direct path when it leaves a rifle barrel?**
3. **If a .22-caliber Long Rifle high-velocity bullet is fired in a 10 mph, wind coming from an 11 o'clock angle, how many inches will the bullet deflect at 50 yards?**
4. **Given the same conditions as in Question 3 above, how much deflection is present, in inches, at 200 yards?**

Gunning Calculations

The information that follows explains how to make basic gunning calculations using any calculator you have on hand. A number of examples have been provided. Online calculators are very helpful if you have access to them. One example is www.shooterscalculator.com.

Bullet Energy. To find the striking energy of a bullet when the velocity at impact and the weight of the bullet in grains are known, follow these steps:

1. Enter velocity value
2. Press the Multiplication key
3. Enter the velocity value again (to square)
4. Press Multiplication key
5. Enter bullet weight in grains
6. Press Division key
7. Enter the number 450,240
8. Press Equals key
9. Answer displayed as the striking energy in foot/pounds

Example. Let's find the striking energy of a 405- grain bullet with a velocity of 1,930 feet per second. All figures are at the muzzle.

Therefore, the energy of the 405-grain bullet at a velocity of 1,930 fps is 3,350 foot/pounds.

Steps	Displayed;
1. Enter velocity value,1,930	1,930
2. Press the Multiplication key	1,930
3. Enter velocity value again, 1,930	1,930
4. Press Multiplication key	3,724,900
5. Enter weight of bullet, 405	405
6. Press Division key	1,508,584,500
7. Enter number 450,240	450,240
8. Press Equals key	3,350
9. Answer in foot/pounds	3,350

The above computation was done on a basic calculator. If using a scientific calculator instead, steps 1,2,3, and 4 may be combined by entering the velocity (1,930) and pressing the Square key (x2). This will give you the figure 3,724,900. The calculations will then continue with step 5.

Sectional Density. Sectional density is the weight of a bullet in relation to its diameter. It is determined by the bullet's weight (in pounds), divided by the square of its diameter (in inches). This figure is used as a gauge for determining flight characteristics. To determine sectional density, perform the following steps:

1. Enter weight of bullet in grains
2. Press Division key
3. Enter the number 7000 (to convert grains to pounds)
4. Press Division key
5. Enter bullet diameter
6. Press Division key
7. Enter bullet diameter again
8. Press Equals key
9. Answer in pounds per inch

Example. Find the sectional density of a 180-grain bullet with a diameter of .308 inches. 7.

Steps	Displayed;
1. Enter weight of bullet in grains	180
2. Press the Division key	180
3. Enter number 7,000	7,000
4. Press Division key	0.0257
5. Enter bullet diameter, 0.308	.308
6. Press Division key	0.0835
7. Enter bullet diameter, 0.308	.308
8. Press Equals key	0.271
9. Answer in pounds per inch	0.271

The bullet in question has a sectional density of 0.271 pounds per inch.

Telescopic Sight Adjustments. Many shooters mount telescopic sights on their rifles for better accuracy, as shown in Figure 6. To determine the number of clicks on the scope adjustment to move a bullet on a target a certain distance, do the following:

1. Enter the distance the bullet should move in inches
2. Press the Division key
3. Enter the number of inches that one click moves the bullet
4. Press the Equals key
5. Answer on panel as the number of clicks required



Figure 6: Many shooters equip their rifles with telescopic sights. Using your calculator, you can determine quickly the number of clicks required for proper sight adjustment.

Example. In sighting-in a .243 Winchester rifle at 100 yards, using a Lyman 4x scope which has a ¾" click value at 100 yards, the first two shots are placed on the target 4½" to the left of the point of aim.

Steps	Displayed;
1. Enter distance the bullet should move, 4.5	4.5
2. Press the Division key	4.5
3. Enter number 0.75	0.75
4. Press Equals key	6
5. Answer as number of clicks required	0.271

Therefore, 6 counterclockwise clicks of the windage adjustment knob should put the bullet dead center at 100 yards.

Correcting Factory Velocity Tables. The factory-published velocities of a given load are usually based on a barrel length of 26", with some exceptions. To find the actual velocity in a given rifle, the following correction table may be used.

Barrel Length	Multiplication Factor
26"	1.000
25"	0.993
24"	0.985
23"	0.979
22"	0.969
21"	0.964
20"	0.954
19"	0.944
18'	0.939

To use this table, merely multiply the published factory velocity by the multiplication factor opposite the barrel length in question.

Example. The factory-published velocity of a 139-grain bullet in 6.5 x 54mm cartridge is 2,580 feet per second. What is the velocity in an 18" carbine barrel?

Steps	Displayed;
1. Enter factory velocity	2,580
2. Press the Multiplication key	2,580
3. Enter factor from table opposite 18"	0.939
4. Press Equals key	2,422
5. Answer in feet per second	2,422
Therefore, the actual velocity of an 18" barrel is 2,422 feet per second	

CALCULATING BULLET DROP

One of the more convenient devices for determining bullet drop is the *Powley High Velocity Chart*. This is now available online at http://kwk.us/powley.html (Figure 7, on page 12.) The late Homer Powley, former Chief Ballistician at *Colt Industries*, introduced this chart in the mid-1950s. To use this chart to calculate the drop of a particular bullet, the following factors must be known:

1. The actual velocity of the bullet in the rifle in which it is fired; not the published velocity.
2. The ballistics coefficient of that bullet.
3. The height of the line of sight above the bore.

The actual velocity of a bullet, fired in a given rifle, can be determined with an instrument for measuring velocity called a chronograph. These instruments are currently available from several sources at a starting price of about $80. However, for all practical purposes, the velocity for a given rifle can be estimated as discussed previously. To do so, use the published velocity for a given load (obtained from handloading manuals) and then adjust this velocity according to the barrel length given in the manual and the barrel length of the rifle in question. Use the same method of calculating the velocity as was used for the 6.5 x 54mm cartridge in an 18" carbine barrel; only change the barrel length to suit the particular rifle under study.

The ballistic coefficient of a bullet determines its ability to resist air drag and maintain velocity and energy as it travels toward the target. Two methods are commonly used to

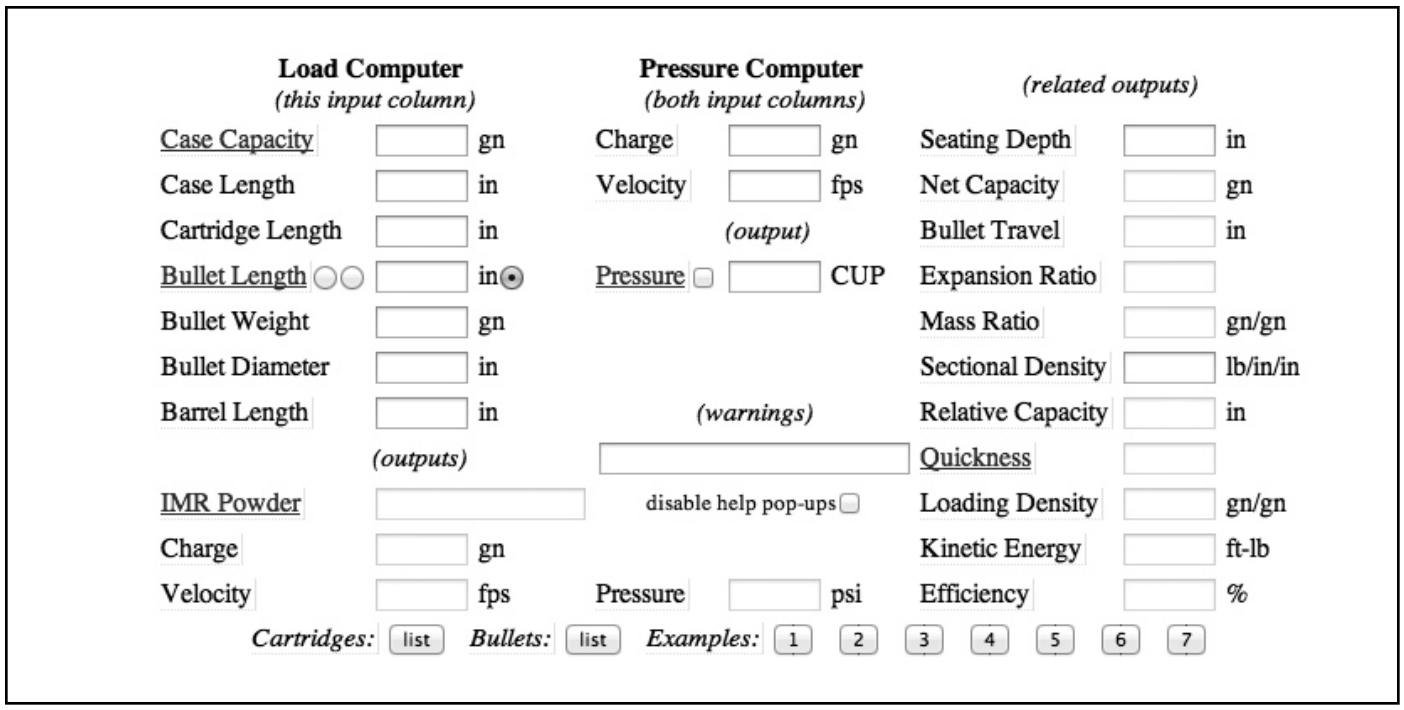


***Figure 7**: The Powley chart is one way to determine bullet drop. It is now available online for convenient calculating.*

determine the ballistic coefficient of a bullet. The more popular one was introduced in the 1930s by Wallace H. Coe and Edgar Beugless, ballistics engineers at Du Pont. This method compares an actual bullet to a point shape chart, and when the closest possible match is made, the chart provides a point shape factor — a number which is then divided into the bullet sectional density to give the ballistic coefficient.

The other method is direct measurement by means of firing tests. The test range must be instrumented so that both muzzle velocity and flight time over a known range are measured for each shot fired. A computer program then derives the ballistic coefficient of each test bullet from these measurements.

For the average shooter, the best and easiest way to obtain the ballistic coefficient of a given bullet is from the bullet's manufacturer. Tables, like the one shown in Figure 8, are available that give the sectional density, ballistic coefficient, etc., for nearly every bullet manufactured.

The third factor — line of sight above the bore — can vary from gun to gun, but for open sights assume ½": for conventional scope mounted rifles, assume 1½", and for scopes with see-through mounts, 2 inches.

Assume that you want to find the bullet drop of a .243, 75-grain Sierra hollow-point bullet fired in a .243 Winchester rifle at an actual velocity of 3,100 feet per second. Conventional scope mounts are used. The ballistic coefficient from Sierra's Reloading Manual is .265 for this bullet. With this data, we can now calculate the bullet drop using Powley's chart.

Attach the chart to the wall so that it is at a convenient height, so that it can be easily reached as you're using it. Take a piece of heavy black thread about 40" long and tie a thumbtack at each end of this thread. Since we are using a rifle with conventional scope mounts, one of the tacks will be placed at the 1.5" mark on the chart, as shown in Figure 9. We are now ready to calculate the trajectory of the .243, 75-grain bullet from muzzle to 500 yards.

The corrected (actual) velocity of our example bullet is 3,100 feet per second. Find the vertical column headed "MV" on the chart; 3,100 will be located in the lower right section of the chart. You will also find the ballistic coefficient numbers

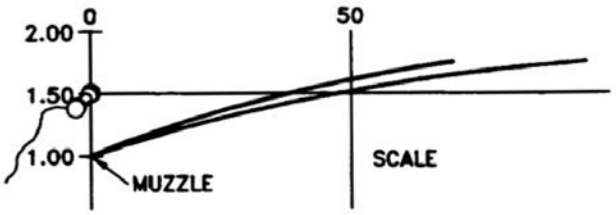


***Figure 9**: Place a tack, with a string attached, at the 1.5" mark on the Powley chart.*

30 Caliber (.308″ Dia.) 165-Grain Spire Point						
Sectional Density: .248 Ballistic Coefficient: .400						
Range	Muzzle	100 m.	200 m.	300 m.	385 m.	500 m.
Velocity (fps)	3000	2735	2484	2249	2062	1827
Energy (ft./lbs.)	3298	2741	2261	1854	1558	1223
Traj.: 100 m. zero	– 1.5″	0.0″	– 4.2″	– 15.2″	– 31.2″	– 64.9″
Traj.: 200 m. zero	– 1.5″	2.1″	0.0″	– 8.8″	– 23.1″	– 54.3″
Traj.: 300 m. zero	– 1.5″	5.1″	5.9″	0.0″	– 11.7″	– 39.6″
Traj.: 385 m. zero	– 1.5″	8.1″	12.0″	9.1″	0.0″	– 24.3″
Traj.: 500 m. zero	– 1.5″	13.0″	21.8″	23.8″	18.8″	0.0″

***Figure 8**: Sample page from a Hornady Handbook of Cartridge Reloading showing the bullet type, sectional density, and ballistic coefficient.*

— minus the third decimal. Trace an imaginary line from the ballistic coefficient of this bullet (.265) straight across to the extreme right vertical line, which will end at curve 38. Place a thumbtack here.

Let's assume that we wish to use a 200-yard zero, meaning the bullet will strike dead on at this distance from the muzzle. Follow curve 38 from the bottom reference mark until it intersects the vertical line marked 200 on the chart. Make a light pencil mark at this intersection point (Figure 10).

Pick up the loose tack at the other end of the thread and stretch it to the right so that it crosses directly over the 200-yard zero point that you just marked. Secure the tack to the wall, to the right of the chart. This thread represents the line of sight relative to 200-yard zero.

Now let's calculate the bullet drop at 250 yards, 300 yards, and 400 yards. Follow curve 38 to where it intersects the vertical line marked 250. Make a light pencil mark at this point. Using a metal scale that is calibrated in tenths of an inch, measure the distance, against the 250-yard vertical line, between the thread and the pencil mark you just made. The figure is 1.85", but since the chart scale is 1" = 2" (half-scale), this figure will be doubled. Therefore, 2" x 1.85" = 3.7" below the line of sight.

To continue, the distance (measured with the engineer's scale) from the thread to curve 38 where it intersects the 300-yard vertical line is 4.4 inches. This, doubled, would be an 8.8" drop at 300 yards. At 400 yards the measured distance is 12.5" actual drop.

Now, let's check the Sierra Reloading Manual to see how close our figures compare to Sierra's calculations. Sierra has no figure for 250 yards, but at 300 yards they show that this bullet will drop 7.87" as compared to 8.8" on the Powley chart—nearly an inch off. At 400 yards, Sierra shows the bullet drops 24.33" as compared to our 25"—about 2/3" off. However, neither case is enough of a difference to matter.

SELF-TEST QUESTIONS

Please check your answers on page 17.

5. ***True or False*. Sectional density is the weight of a bullet in relation to its diameter.**
6. **If the published muzzle velocity of a .30-30 cartridge is 2200 fps in a 26" barrel, what will the velocity be in a 20" barrel?**
7. **Find the sectional density of a 200-grain bullet with a diameter of .430 inches.**
8. **The name of one chart used to calculate bullet drop is _____.**

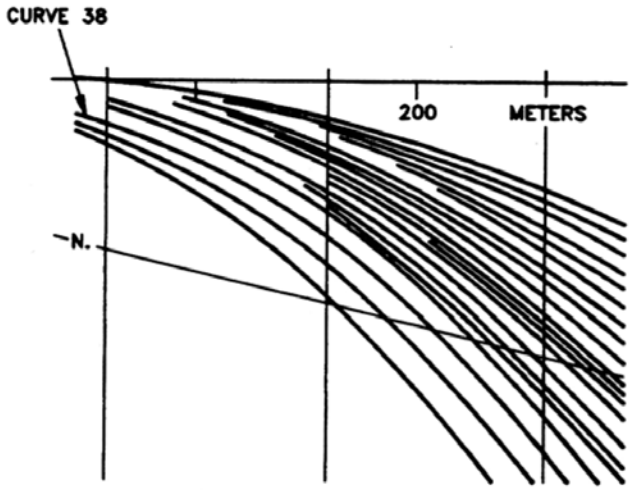


***Figure 10**: Make a light pencil mark where curve 38 intersects the vertical line marked 200 on the chart.*

Ballistic Glossary

ANVIL: In the priming system, a fixed metallic point against which the priming mixture is crushed and thereby detonated by the action of the firing pin (Figure 11).

BALL: Early term for bullet. Still used in military nomenclature.

BALLISTICS: The science of projectiles in motion.

BALLISTIC COEFFICIENT: The ratio of the sectional density of a bullet to its coefficient of form. Represents the projectile's ability to overcome the air resistance in flight.

BATTERY CUP: A type of primer in which anvil and primer cup are supported in an outside cup. Shotshell primers are an example of this type.

BEARING SURFACE: That portion of a bullet's surface that touches the bore in moving through the barrel.

BERDAN: A type of primer with no integral anvil. The anvil is formed in the bottom of the primer pocket. This is common in Europe, but is named after Col. Hiram Berdan, the inventor, an American.

BOLT THRUST: The actual force on the face of the bolt of a rifle caused by the pressure of bumming powder gases.

BORE: The inside of any gun barrel and, in rifled arms, the diameter of the barrel before the rifling is cut.

BOXER: The standard American type of primer, named after the inventor, Col. Boxer, of the British Army (Figure 11).

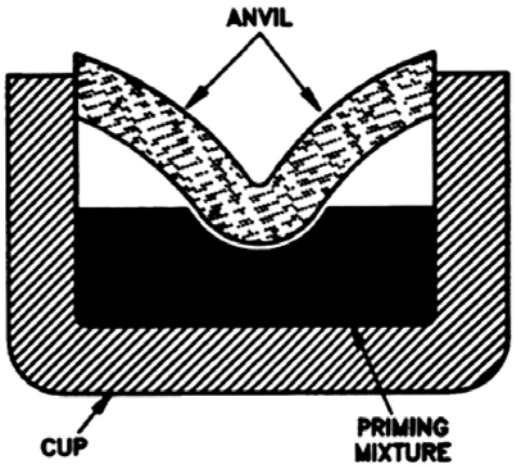


Figure 11: A cross-sectional view of a Boxer primer, showing the anvil, cup and priming mixture.



Figure 12: Four types of bullets: .224, 9mm, .308, and .45. A bullet is a missile. When fired, it becomes a projectile.

BULLET: The missile only, which becomes a projectile when in flight. Not the same thing as the cartridge (Figure 12).

BURNING RATE: A relative term meaning the rapidity with which a given powder burns in comparison with other powders.

CALIBER: The approximate bore or groove diameter expressed in decimals of an inch, otherwise in the metric system. Frequently compounded to indicate the powder charge, the date of adoption, the case length, or the proprietor or designer; that is, .30-40, .30-06, 7 x 57mm, .375 Holland & Holland, or .257 Roberts, respectively.

CAP: See Primer.

CARTRIDGE: A complete unit of assembled ammunition: case, powder, primer, and bullet. Usually applied only to rifle and pistol ammunition, but occasionally to shotshells.

CENTERFIRE: This refers to a centrally located primer in the base of metallic cartridges. Most centerfire cartridges are reloadable.

CHAMBER: That part of the bore, at the breech, formed to accept and support the cartridge.

CHARGE: The amount of propellant powder measured into the case in loading. It also refers to the amount of shot measured into the shotshell.

CHOKE: A constriction at the muzzle of a shotgun barrel, designed to control or reduce the spreading and dispersion of the shot charge.

CHRONOGRAPH: An instrument to measure the velocity of a projectile.

COMPONENTS: Those parts which go into the making of a cartridge.

CORDITE: A double-base powder used mainly in Great Britain.

DRIFT: The deviation of a projectile from the line of departure due to its rotation or spin.

DROP: The distance a projectile falls, measured or calculated from the line of departure.

ENERGY: The amount of work capable of being done by a projectile at a given range, expressed in foot/pounds.

EROSION: The wearing away of the bore of an arm due to friction from the bullet or shot, or from hot powder gases.

FLASH HOLE: The hole leading from the primer pocket into the body of the cartridge case.

FOOT/POUND: A unit of kinetic energy equal to the effort required to raise one pound to a height of one foot against normal gravitational force.

FREE BORE: The distance, if any, which a bullet travels upon firing before it contacts the rear portion of the rifling.

GRAIN: In weight measure 7,000 grains equal 1 pound; 437.5 grains equal 1 ounce.

GROOVES: Spiral cuts or impressions in the bore of a firearm which cause a bullet to spin as it moves through the barrel.

GROUP: The pattern made, at the target, of a number of shots fired with one aiming point and usually one sight setting. The size of the group is usually measured from center to center of the holes farthest from each other.

HANGFIRE: The ignition in a cartridge which is delayed beyond the normal time after the firing pin has struck the primer.

HEEL: The edge of the base of the bullet.

HOLLOW-POINT: Bullet design feature; an axial hole at point of bullet.

IGNITION: The setting on fire of the propellant powder charge by the primer.

KEYHOLE: The imprint of a bullet, in a target, which shows that the bullet was not traveling point-on at the time of impact.

LANDS: The spiral raised portion of a bore remaining after the grooves have been cut or formed.

LEADE: See Throat.

LINE OF DEPARTURE: That particular line at which a bullet leaves the muzzle of an arm. The bullet immediately falls away from this imaginary line.

LINE OF SIGHT: The straight line through the sights of a gun to the point of aim.

MID-RANGE TRAJECTORY: Usually refers to the highest vertical distance of a bullet above the line of sight at a point approximately halfway from the muzzle to the target, or point of aim. Sometimes abbreviated as MRT.

MINUTE-OF-ANGLE: A unit of angular deviation equal to one-fiftieth of a degree. Although usually approximated at 1" to the 100 yards, it is actually equal to 1.05" per 100 yards. Sometimes abbreviated as MOA.

MISFIRE: Complete failure of a cartridge to fire after the primer is struck by the firing pin.

MUZZLE: The front end of a barrel. The point at which a projectile leaves the barrel.

MUZZLE BLAST: The blast of the hot powder gases from the muzzle of the gun with the attendant flash and noise.

MUZZLE ENERGY: The energy of a bullet at the muzzle. See Energy.

MUZZLE VELOCITY: See Velocity.

OGIVE: The radius of the curve of the bullet nose, usually expressed in calibers.

PATTERN: The way a shotgun places its shot load. Generally measured as the percentage of a full shot charge that is placed in a 30" circle at 40 yards.

POWDER: The propellant material used in most firearms. Divided into two basic types: smokeless powder and black powder. It is produced in a wide variety of types, forms, and brand names intended for specific applications.

PRESSURE: The pressure exerted by a burning charge of powder in the chamber of a gun. Normally expressed as the peak pressure in pounds per square inch (psi).

PRIMER: Also called cap, deriving from percussion cap, which is the priming form used with some muzzleloading arms. In a centerfire cartridge, the small metal cup containing a detonating mixture which is used to ignite the propellant powder. The primer is seated in the primer pocket in the base of the cartridge case. The standard American type of primer, the Boxer, also contains an anvil. In a rimfire cartridge, the priming mixture is contained within the rim of the case.

RIFLING: Parallel spiral grooves cut or impressed into the bore of rifles and pistols in order to make the bullets spin, insuring a steady, point-on flight to the target. See Grooves and Lands.

RIMFIRE: Cartridges that contain the priming mixture within the rim. This type is not reloadable under practical conditions.

ROUND-NOSE: A blunt, spherical, nose-shaped bullet design feature.

SECTIONAL DENSITY: A bullet's weight (in pounds), divided by the square of its diameter (in inches).

SHANK: The cylindrical section of a bullet.

SHOT: The lead alloy spheres, sometimes copper or nickel-plated, which are used for the projectiles in smoothbore guns (shotguns).

SHOULDER: The sloped or rounded part of a bottlenecked cartridge case.

SLUG: A cup-shaped, hollow-base projectile, usually bearing external precut rifling, intended for adapting shotguns to the hunting of larger game, such as deer. Also used as another term for bullet.

SOFT-POINT: A bullet design feature with a portion of the lead alloy core exposed at the point or nose of a jacketed bullet.

THROAT: That area of the bore immediately ahead of the chamber that tapers to the point where the rifling starts. Also called leade.

TRAJECTORY: The path of the projectile in flight.

TWIST: The angle of the rifling in relation to the axis of the bore. Usually measured by the length of barrel required to make one complete turn.

VELOCITY: The speed at which a projectile travels. Usually measured in feet per second (fps) at a given range.

WILDCAT: A cartridge case formed by altering an existing case to make a shape of case that is not available from the large ammunition companies. A nonstandard cartridge case.

SELF-TEST QUESTIONS

Please check your answers on page 17.

9. **The area of the bore immediately ahead of the chamber is called the _____.**
10. **The hole leading from the primer pocket into the body of the cartridge case is called the _____ .**
11. **What is the edge of the base of the bullet called?**
12. **What name is given the instrument that is used to measure the velocity of a bullet?**

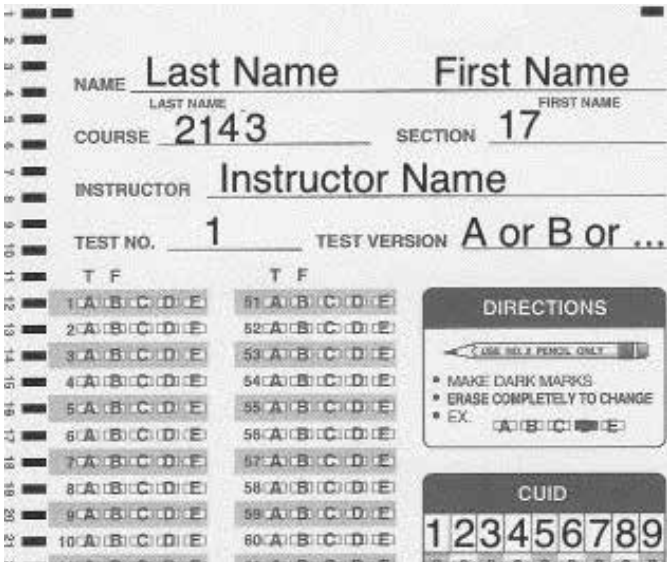
Answers to Self-Test Questions

1. Trajectory.
2. Rifling cut into the bore of the barrel causes the bullet to spin.
3. 0.67 inches.
4. 8.56 inches.
5. True.
6. 2098 feet per second. 2200 x .954 = 2098 fps.
7. 0.1545.
8. Powley High Velocity Chart.
9. Throat.
10. Flash hole.
11. The heel.
12. Chronograph.

Lesson Questions

THIS IS LESSON NUMBER 2197.

Make sure you print your name, student number, and lesson number in the space provided on the Lesson Answer Form. Be sure to fill in the circles beneath your student number and lesson number.



REMINDER: A properly completed Lesson Answer Form allows us to evaluate your answers and send the results and additional study material to you. Do not hold your Lesson Answer Forms to send several at one time. You may run out of study material if you do not send your answers for evaluation promptly.

You may also complete your exam online at www.sdi.edu, click on the *online exams* tab.

1. **Ballistics deals with**
   a. The science of moving projectiles.
   b. Handloading centerfire ammunition.
   c. The heat-treatment of metal.
   d. Handloading rimfire ammunition.

2. **The realm of interior ballistics extends**
   a. From the muzzle to the target.
   b. From the breech to the throat of the chamber.
   c. From the breech of the gun to the muzzle.
   d. From the stock to the barrel.

3. **The realm of exterior ballistics extends**
   a. From the muzzle to the target.
   b. From the breech to the throat of the chamber.
   c. From the breech of the gun to the muzzle.
   d. From the stock to the barrel.

4. **Rifling consists of**
   a. A smoothbore barrel.
   b. Lands and grooves cut in a rifle barrel.
   c. The science of shooting.
   d. Bottleneck centerfire cartridges.

5. **Trajectory is**
   a. The energy produced by a fired cartridge.
   b. The ignition of the primer.
   c. The ignition of the propellant powder.
   d. The pattern and curved path of a bullet in flight.

6. **Heavier bullets**
   a. Sustain their velocity longer than lighter ones.
   b. Lose velocity quicker than lighter ones.
   c. Will hit the ground quicker than lighter ones when dropped by hand.
   d. Are more affected by wind.

7. **In a crosswind of 10 miles per hour, a .22 Long Rifle bullet, with a muzzle velocity of 1,335 fps will be blown downwind how many inches?**
   a. Two inches.
   b. Three inches.
   c. Four inches.
   d. Five inches.

8. **The pressure exerted on the chamber walls when a cartridge is fired is called**
   a. Primer pressure.
   b. Breech pressure.
   c. Powder pressure.
   d. Bullet pressure.

9. Bullet energy is normally expressed in

a. Feet per second.

b. Feet per minute.

c. Foot/pounds.

d. Pounds per square inch.

10. The forward speed of a bullet, usually specified in feet per second, is called

a. Velocity.

b. Recoil.

c. Bullet energy.

d. Kinetic energy.