

## **Angle Shooting - Correcting for the effects of gravity**

*by Ward W. Brien*



There is a physical ballistic problem encountered when shooting on angles that causes the bullet's point of impact to hit high. Shooting on angles is what every hunter experiences while hunting in mountainous terrain. Sheep hunters and deer hunters alike know all too well, that if their target is up or down on an angle, that they must aim low because the bullet will impact high. The reason for this has to do with gravity and the adjusted sight height above the bore of the barrel.

When we zero in our rifle at 100 yards, we are shooting on a flat plane with the full force of gravity pushing down on the bullet. In order to zero properly and get the bullet to strike the bulls-eye, we need to adjust the sight height above the bore of the barrel for this particular condition, (shooting on a flat plane) so that when the bullet leaves the bore of the barrel it arcs up into the full force of gravity, and then drops down onto the bulls-eye.

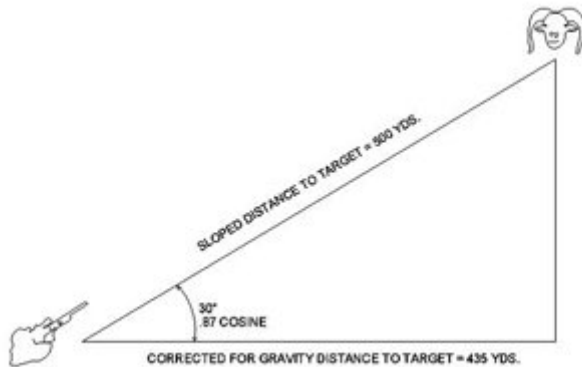
However, when we shoot on an incline or decline (up or down on an angle) the force and effect of gravity is less on the bullet; but the sight height above the bore of the barrel remains the same, or adjusted for shooting on a flat plane.

Because of this, the bullet will have a flatter trajectory and strike the target higher than where our intended point of aim was. It is imperative that when we are shooting up or down on an angle that we eliminate the guesswork, and correct the straight line distance to the target or "sloped distance," to the, corrected for gravity, distance to target.

Now, this is an easy adjustment; a simple equation that will put you very close to right on target. However there are three ways to obtain this and one is more accurate than the other.

The first method is called the field expedient "Rifleman" method. As an example, when a surveyor is shooting a mountain top for mapping purposes, he uses an instrument called a theodolite. The theodolite tells the surveyor the angle of his aim. His/her goal is to obtain the base of the triangle distance, or flat line distance. Hence, simple geometry comes into play. The

surveyor notes the angle that he is holding at, then goes to his data book and obtains a cosine number of that angle, which he then multiplies to the sloped distance.



Here you can see the sloped distance to target equals 500 yards and the angle that the hunter is holding on is 30 degrees (cosine number of .87). To obtain the bottom leg of the triangle, you would multiply the cosine number of .87 to the 500 yards. (.87 X 500 yds. = 435 yds.) This gives you the corrected distance as if you were shooting on a flat plane, with the full force of gravity affecting the bullets path of flight.

Below, referencing a .300 Remington Ultra Mag, utilizing a flat shooting 180 grain Nosler Partition bullet, with a velocity of 3250 feet per second, the uncorrected for gravity distance of 500 yards to target would cause the bullet's point of impact (under the field expedient method) to hit approximately 13.2 inches high; or 1.75 minute of angle. Please see the Night Force ballistic Targeting Software Generated Angle Drop chart below.

**SIGHT ADJUSTMENTS vs INCLINE ANGLE**  
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.300 Remington Ultra Mag - Nosler Partition 0.308" 180gr Spitzer  
altitude=0, temp=70F, pres=29.53inHg, vel=3250fps

Angle	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
Cosine	1.00	1.00	0.98	0.97	0.94	0.91	0.87	0.82	0.77	0.71	0.64	0.57	0.50	0.42	0.34	0.26
25	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.75	3.75	3.75	3.75
50	1.00	1.00	1.00	1.00	1.00	0.75	0.75	0.75	0.75	0.75	0.75	0.50	0.50	0.50	0.50	0.25
75	0.25	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	-0.25	-0.25	-0.25	-0.50	-0.50	-0.75	-0.75
100	0.00	0.00	0.00	0.00	0.00	-0.25	-0.25	-0.25	-0.50	-0.50	-0.50	-0.75	-0.75	-1.00	-1.00	-1.25
125	0.00	0.00	0.00	0.00	0.00	0.00	-0.25	-0.25	-0.50	-0.50	-0.75	-0.75	-1.00	-1.00	-1.25	-1.50
150	0.25	0.25	0.25	0.25	0.25	0.00	0.00	-0.25	-0.25	-0.50	-0.50	-0.75	-1.00	-1.25	-1.25	-1.50
175	0.50	0.50	0.50	0.50	0.50	0.25	0.25	0.00	0.00	-0.25	-0.50	-0.75	-1.00	-1.25	-1.25	-1.50
200	1.00	1.00	0.75	0.75	0.75	0.50	0.50	0.25	0.00	0.00	-0.25	-0.50	-0.75	-1.00	-1.25	-1.50
225	1.25	1.25	1.25	1.25	1.00	1.00	0.75	0.50	0.50	0.25	0.00	-0.25	-0.75	-1.00	-1.25	-1.50
250	1.75	1.75	1.75	1.50	1.50	1.25	1.00	1.00	0.75	0.50	0.25	-0.25	-0.50	-0.75	-1.25	-1.50
275	2.25	2.00	2.00	2.00	1.75	1.75	1.50	1.25	1.00	0.75	0.50	0.00	-0.25	-0.75	-1.00	-1.50
300	2.50	2.50	2.50	2.50	2.25	2.00	1.75	1.50	1.25	1.00	0.75	0.25	0.00	-0.50	-1.00	-1.50
325	3.00	3.00	3.00	2.75	2.75	2.50	2.25	2.00	1.75	1.25	1.00	0.50	0.00	-0.25	-0.75	-1.25
350	3.50	3.50	3.50	3.25	3.25	3.00	2.75	2.50	2.00	1.75	1.25	0.75	0.25	-0.25	-0.75	-1.25
375	4.00	4.00	4.00	3.75	3.75	3.50	3.25	2.75	2.50	2.00	1.50	1.00	0.50	0.00	-0.50	-1.00
400	4.50	4.50	4.50	4.25	4.25	4.00	3.50	3.25	2.75	2.50	2.00	1.50	0.75	0.25	-0.25	-1.00
425	5.25	5.25	5.00	5.00	4.75	4.50	4.00	3.75	3.25	2.75	2.25	1.75	1.00	0.50	-0.25	-0.75
450	5.75	5.75	5.50	5.50	5.25	5.00	4.50	4.25	3.75	3.25	2.50	2.00	1.25	0.75	0.00	-0.75
475	6.25	6.25	6.25	6.00	5.75	5.50	5.00	4.50	4.25	3.50	3.00	2.25	1.75	1.00	0.25	-0.50
500	7.00	6.75	6.75	6.50	6.25	6.00	5.50	5.00	4.50	4.00	3.25	2.75	2.00	1.25	0.25	-0.50
525	7.50	7.50	7.25	7.25	7.00	6.50	6.00	5.50	5.00	4.50	3.75	3.00	2.25	1.50	0.50	-0.25
550	8.25	8.25	8.00	7.75	7.50	7.00	6.75	6.25	5.50	5.00	4.25	3.50	2.50	1.75	0.75	-0.25
575	8.75	8.75	8.75	8.50	8.00	7.75	7.25	6.75	6.00	5.25	4.50	3.75	2.75	2.00	1.00	0.00
600	9.50	9.50	9.25	9.00	8.75	8.25	7.75	7.25	6.50	5.75	5.00	4.25	3.25	2.25	1.25	0.25

To the average hunter, these trajectories, at first, may not appear to be significant, but as an

experienced shooter you know that they are; and the angle that you will be holding on demands a correction. As an example, let's say that your rifle shoots an average group size of one inch at 100 yards (large for a pro-grade rifle). At three hundred yards the group size could hypothetically open to three inches; at five hundred yards, five inches. So, if you are going to be thirteen inches high at 500 yards if uncorrected for gravity, then you can add an additional five inches to that, in any direction. This is not difficult to see; math is math and science is science and when the math is done correctly, one round will put one animal down.

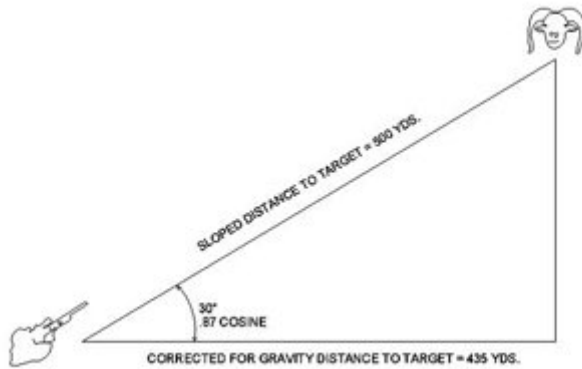


Figure 3 – Angle Drop Table for the

300 Rem Ultra Mag

The U.S. Military as well as other Government agencies, train all of their Precision Marksmen on how to obtain the corrected for gravity distance to target. The original method of approach was to utilize a Protractor, string and paper-clip. The string was tied to the center of the protractor and weighted with the paper-clip. When the Marksman was aiming at his target, the protractor was held in place with the weighted string along the side of the receiver inline with the barrel. The Marksmen would then carefully grab the protractor and string, and obtain the angle that he was holding on. Then, the Marksman would go to his data book and obtain the cosine number, then do the math; very simple and very straight forward. Only today there is an easier, faster and more dependable method of obtaining the cosine number; and that is by using an “Angle Cosine Indicator” manufactured by “Sniper Tools Design Company”.



The Angle Cosine Indicator, (ACI), is a widely expected method of obtaining the cosine number of the angle that the hunter is holding on, by all Branches of the U.S. Military and militaries throughout the world. It is a simple tool for hunters who hunt in mountainous terrain and is a vault solid precision instrument. It is manufactured from aircraft grade aluminum and anodized a flat black color. It fastens onto your rifle or your scope; either by a standard Weaver Base scope ring, or as seen in figure 4, by “Badger Ordnance’s” military specific picatinny rail mount. When the rifle is held on target, the “ACI” indicates the cosine number of that angle by means of a highly visible index mark; in addition, the cosine numbers transverse the body in five degree increments. The ACI is easily zeroed to your rifles bore by simply loosening the side screw and rotating the body until the zero cosine number sits inline of the index mark.

To install the Angle Cosine Indicator you will first need to decide on your method of mounting; either a Weaver base scope ring or a Badger Ordnance’s Picatinny rail mount. Once that is decided, you will level the bore of your barrel by placing a spirit bubble level on the inside rail of your receiver, which is where your bolt lugs ride on. Once the bore is level, install and zero the ACI, insuring that it is indeed level with the bore of the barrel and the zero cosine number is sitting ontop of the index mark. Once that is accomplished, you are ready to hunt. The following is the procedure for utilizing the ACI while in the field.

- 1) You spot your target.
- 2) Range / obtain the distance to your target by either utilizing a laser range finder or a ranging reticle.
- 3) Aim at your target and then look off to the side of your rifle at the Angle Cosine Indicator and obtain the indicated Cosine number.
- 4) Multiply the cosine number to the distance to your target, which will give you a corrected for gravity distance.

For example, 500 yards X .7 (45 degrees) = 350 yards. Now, look at your data card to obtain your hold for the 350 yard target distance, and adjust your turrets as specified. However, this is the least accurate method of the three.

2) In the second method of obtaining the corrected for gravity distance to target, the ACI still plays its role, however the cosine number is multiplied to the hold data from your "data card." When I instruct angle shooting to my Students, I teach how to utilize Night Force Ballistic Targeting Software which is loaded onto a Pocket PC, to manufacture a data card. The procedure is as follows:

1. Utilizing a Kestrel hand held weather station, obtain the temperature, barometric pressure and humidity.
2. Input this data into the data entry points of the software.
3. Pick the "Drop Table" button.

There is a little bit more to this than what I have mentioned, however this procedure produces an electronic data card with distances in one, five, ten, twenty, twenty-five and fifty yard or meter increments; your choice. I then have the Students copy this data card over to small "write in the rain" notebook paper. Then, place the Pocket PC back into their pack and either tape the card to their stock or place it in their jersey pocket. While in the field and after obtaining the distance to target, the data card is reviewed, and the cosine number is multiplied directly to the hold, as depicted on the data card. This method is more accurate than the "Rifleman" method and is called the "Improved Rifleman" method. Looking above at Figure 3, if the target is at 500 yards, the hold for that distance is 7 moa. If you were aiming at a 45 degree angle, the cosine would be .7 and the calculation would be as follows:  $.7 \times 7\text{moa} = 4.9\text{ moa}$ .

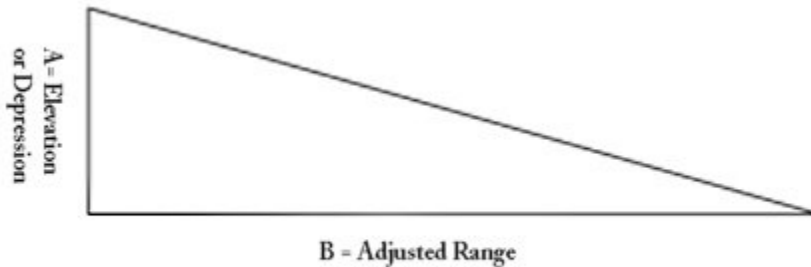
However the most accurate method is to input your meteorological data, (temperature, barometric pressure and humidity) directly into the "Night Force" ballistic targeting software. This is because the software takes into account the fact that the bullet has its own unique velocity, ballistic coefficient, time of flight, and deceleration curve. Utilizing this software can be as much as eight minute of angle more accurate than the Rifleman method and eliminates the guessing game once associated with angle shooting.

## The Angle Cosine Indicator

By Hugo Teufel, "Angle shooting". June 2000

After reading the wind and distance to target, the slope angle of fire is one of the least understood and equally important variables of long range shooting. Whether shooting up or down at a target, the bullet will impact high due to the cause and effects of gravity.

The subject of angle shooting has been covered in a few publications, for example, Captain S., "Shooting at Elevated Targets," Tactical Shooter (January, 1999); Lau, The Military and Police Sniper, pp. 181-85; and Plaster, The Ultimate Sniper, pp.194-200. Unfortunately, many shooters do not understand angle shooting clearly. Because gravity typically is the primary variable in angle shooting, the key to successful angle shooting is to determine the adjusted range to the target. That is, the range at which gravity has an effect on the projectile. How do we determine this range? Picture a right triangle:



The shooter ("S") is on the peak of a hilltop. His target, "T", is 500 yards distant, line-of-sight, at a 30-degree angle in a valley adjacent to the hilltop. "A" is the elevated distance from the Target's altitude to the Shooter's altitude, or slightly over 263 yards, "C" is the actual range from S to T, or 500 yards, and "B" is horizontal or "adjusted" range from S to T. Recalling our high school algebra and modifying the formula for right triangles,  $A^2 + B^2 = C^2$ , we can calculate the adjusted range as follows:  $C^2 - A^2 = B^2$ . "B," in our example, is 425 yards, but we can only calculate the adjusted range if we know the elevation. However, neither our hypothetical shooter, nor we, typically will have any more data beyond the actual range to the target and the angle of elevation or depression.

What does our hypothetical shooter do? He determines the angle of depression or elevation, 30 degrees in our example, and then turns to calculus. Determining the cosine of the angle (typically read off of a chart), the shooter multiplies the actual distance, "C," by the cosine to get the horizontal, or "adjusted" range, "B." But first, he must determine the angle of elevation or depression. (Inclination or declination)

To do so, special operations forces (SOF), Marine Corps Scout/Snipers, and regular, "leg" Army snipers typically have relied upon inverted plastic protractors, with a string running through a hole placed at the center of the base, to indicate angle. Of course, using the protractor, one must read the upside down number and subtract it from 90 degrees, to determine the angle of elevation or depression. Next, the shooter must compare the angle to a chart with corresponding cosines. Taking the proper cosine, the shooter multiplies the actual range to get the corrected or adjusted range.

The protractor, as a field expedient method, is good. It is not very rugged, and it certainly is not ideal. Two other tools, based upon the same concept, are available. The first, the Slope Doper [see Hugo Teufel, "The Slope Doper," Tactical Shooter (---, 2000)] is made of aluminum and is, essentially, a reversed protractor, with the angles and their corresponding cosines, as well as the formula, on the front of the tool. The second, is the Mildot Master, which has on its backside, various angles. The shooter attaches a string and weight to the upper left rivet of the Mildot Master, allows it to hang loose, orienting the Mildot Master to the elevation or depression, to read the angle. The shooter then turns over the Mildot Master, using the slide rule that is the heart of this tool to determine the adjusted range. As well, some data books may have charts with elevation adjustments for various angles at various distances and angle cosines for various angles (e.g., T.R.G.T.-L.L.P.'s "Sniper Data Book"), and some laser range finders have the ability to calculate adjusted range.

The Slope Doper and the Mildot Master are well-designed, useful tools, and laser range finders are interesting pieces of equipment. The Mildot Master's logarithmic slide rule gives it an advantage, in that the operator need not perform any calculations on paper, or with a calculator. The shooter need only determine actual distance and angle; the Mildot Master's slide rules handle the rest. The Slope Doper and Mildot Master have one potential drawback; not being attached directly to the operator's rifle, it is possible that in reading the angle of elevation or depression, the shooter or his spotter/partner may misread the angle (a slight problem/possibility), or break cheek-weld and proper positioning behind the rifle (a much more likely possibility). And laser range finders? Experienced shooters know that anything requiring batteries will have the batteries die when the shooter most needs that piece of equipment. Better to rely on simple, foolproof tools.

What to do? A new device, called the "Angle Cosine Indicator" ( or "Green Pill"), from The Sniper Tools Design Company, may be the answer. The latest aid for snipers and practical field shooters who must engage elevated or depressed targets, the ACI still requires the shooter (or, more likely, his spotter/observer) to perform a calculation. The ACI attaches to the shooter's scope, minimizing the possibility of breaking cheek-weld and losing sight of the target.

Solidly constructed, the ACI is made from aircraft grade aluminum and anodized olive drab. The ACI is the design of Ward Brien, former U.S. military servicemen with design contributions by his friend Ping Lee.

The ACI is intended primarily for use on a scoped rifle. The Sniper Tools Company suggests using a scope ring (e.g., Leupold QRW, Badger Ordnance rings) mounted onto the scope tube, at a 90-degree angle. The ACI attaches to the ring as if it were a scope mount. The design is well executed, tactical, practical, adaptable, and convenient. It also aids in actually protecting the scope. Alternatively, the company suggests hand holding the ACI or lashing the ACI to the day scope, spotting scope, binoculars or bow. Having mounted the ACI on both my Armament Technology AT1-M24, with 10-power Bausch & Lomb Tactical, and my Springfield Supermatch M1A with 10-power Leupold Mark IV M3, I urge shooters considering the ACI to consider carefully the scope ring used to mount the ACI. Too robust a ring probably will not mount on a very low-mounted scope.

How does the ACI work? When properly mounted and the rifle is elevated or depressed, the ACI (with the cosine numbers in five degree increments) bypasses the angle and, instead, indicates the corresponding cosine number of the angle of the elevation or depression. The shooter or his observer/spotter need only multiply the actual range by the cosine number to get the adjusted range. Having done so, the shooter adjusts the elevation on his scope and engages the target. If he has done everything correctly, including compensating for wind (which works along the actual distance of the shot), the shot should be dead on target.

I recently had occasion to evaluate the ACI when I went to the range with snipers from Aurora, Colorado Police Department's SWAT Sniper Team. While on the rifle, I had no problems viewing the window on the ACI. The cosine readings on the device corresponded with the angles as read off the Slope Doper and Mildot Master. Most importantly, I did not have to break my cheek-weld, or otherwise disturb my shooting position. I could stay on target, secure in the knowledge that the cosine corresponds to the angle of elevation or depression of the shot that I would be taking. The question for the day is; how do you turn a 900-yard shot into a 700? Use the ACI! It's quick, easy to use, easy to install, extremely rugged and unaffected by weather.