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IFR

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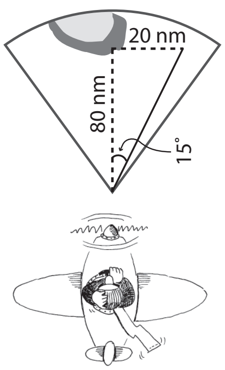
Training controllers at the speed of light ... page 9



Good math ... page 6

Bad Heading ... page 16

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IT'S ALL ABOUT ANGLES

One simple mathematical relationship can be used in everything from descent planning to optimal radar use.

by Neil Singer

Repeat the following fives times: "One degree equals one in 60." Remember that, and you can do nearly any mental math the flying life will ever ask of you. This simple fact can be applied to descent planning, scanning for traffic, onboard radar use and lots more fun flying tricks.

If you sweat during the math questions on *Are You Smarter Than a Fifth Grader?* please skip this paragraph and go straight to how to use the formula without worrying about the "why" behind it. For everyone else, search that dark corner of your mind that holds memories from, if not fifth grade, probably eighth grade. Just next to Sheila Wilson turning you down for the spring semi-formal is a tidbit from Geometry I: The tangent of an angle is equal to the rise over the run.

This means that, for any given angle, the ratio of the "up" (or "down") to the "forward" is always the same. For the angle of one degree, that ratio is .018 to one. One divided by 60—our one-in-60 mentioned above—is equal to a ratio of .017 to one. In high-level math, that's what we call, "close enough."

You should avoid thunderstorms by at least 20 miles, but airplanes don't turn in nautical-mile increments, they turn in degrees.

Looking for 60s

Due to lots of arcane maritime happenings, one nautical mile is close enough to 6000 feet to just call it equal. Hmm, there's a six in that number, which means that, when applying the one-in-60 rule, we find out that one degree, stretched out forward over one mile, will cause a rise or fall in altitude of 100 feet (1/60 * 6000 = 100). Stretch that degree out over 10 miles, and the altitude change equals 1000 feet. Let's move from theoretical to applied mathematics.

Most pilots know that a three-degree angle is the standard for electronic glideslopes and visual glideslope indicators (e.g., VASIs or PAPIs). Remembering that one degree falls 100 feet per mile, a three-degree slope will fall 300 feet in the same distance. Voila; an easy check on whether altitude is appropriate for a given distance for a runway for both IFR and VFR flying. Want to check that you're tracking the correct glideslope rather than a false one? Add miles from the threshold and multiply by 300. Add this to the elevation of the airport (or touchdown zone, if you'd like to be precise), and it should be close to your indicated altitude as you slide down the glideslope.

Let's abuse "close enough" mathematics a little more. If a three-degree slope falls 300 feet in one mile, it will fall 1000 feet in 3.3 miles. Round that down to three and you have a useful trick for en route descent planning. To descend on a three-degree path, every 1000 feet of altitude loss will require three miles.

Flying along at FL410 in our new Mustang, we receive a clearance to

Left: *This math works fine when diverting around thunderstorms shown on your datalink weather, but the real position of the storm may not be as accurate as shown on airboarne radar.*

"Cross the ABC VOR at 11,000 feet." That's 30,000 feet of altitude loss, so 90 miles from the ABC VOR is the point where we'd better start down (30 * 3 = 90). In high-altitude flying, many descent clearances are given this way. ATC doesn't care when you begin your descent, as long as you make it to the assigned altitude X by named point Y. Modern avionics suites have VNAV functions for this, but sometimes a simple "Does this look right?" check can be a violation saver. Not to mention that getting a quick number to start when you're busy, and then fine-tuning it with the fancy avionics later is a reality of the one-pilot cockpit.

If one degree of slope is "one in 60," then a three-degree slope is 3 in 60, or one in 20. This means your vertical speed in knots (the vertical component of the angle) must be 1/20 your groundspeed (the horizontal component). One knot (6076 feet per 60 minutes), almost exactly (how we love to round) equals 100 feet per minute. Dividing by 20 and then multiplying by 100 is the same as multiplying by five. Thus, groundspeed times five equals vertical speed (in feet per minute) required to descend on a three-degree slope.

If a little tailwind gives our Mustang a 400-knot groundspeed, we require a 2000 fpm descent to stay on a three-degree path. Incidentally, this three-degree angle is what ATC expects, so be ready for some "Say rate of descent?" queries, if you're not keeping up.

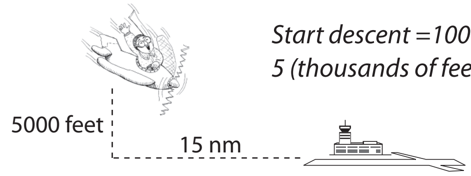
Tilting to 60s

Tilt management is one of the more vexing skills pilots of radar-equipped aircraft are forced to learn. Aim radar too high, and you may scan a thunderstorm at an altitude where all moisture is frozen, which is a poor reflector of radar energy. Scan

THE SWISS ARMY KNIFE OF FLYING MATH

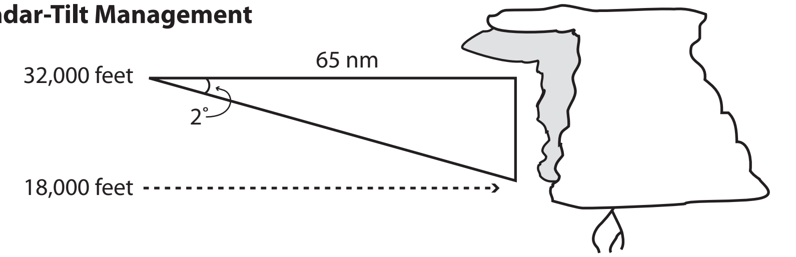
It's a desert topping! It's a floor wax! OK, it's neither, but the one-in-60 rule is still the one formula to remember if you're remembering only one.

En Route or Glideslope Descents



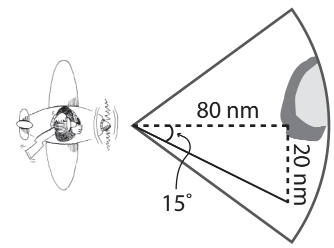
*Start descent =1000s of feet above target * 3 nm*
*5 (thousands of feet) * 3 nm = Start down 15 nm out*

Radar-Tilt Management



$$\text{Tilt} = \frac{\text{1000s of feet to 18,000 feet}}{\text{(nm to storm/10)}} = \frac{\text{14 (thousands)}}{6.5} = \text{2 degrees down}$$

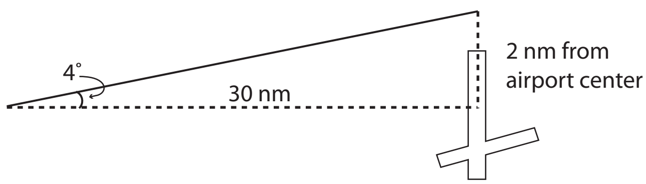
Storm Avoidance



$$\text{Turn} = \frac{\text{nm to displace} * 6}{\text{(nm to storm/10)}}$$

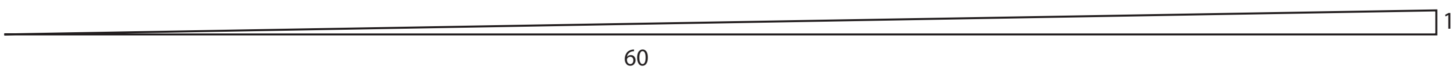
$$\frac{20 * 6}{8} = \text{15 degrees right}$$

Heading for Direct Becomes Heading for Base Entry



$$\text{Turn} = \frac{\text{nm to displace} * 6}{\text{(nm to airport/10)}} = \frac{12}{3} = \text{4 degrees left}$$

For the record, here's what the approximately-one-degree angle really looks like. All the items above are based on this relationship, but not drawn to scale so we can cram more of them on one page.



GIVE OPPOSING TRAFFIC THE FINGER

Your on-board traffic system (please don't call it a "fish finder" on the radio) or ATC points out traffic at 11 o'clock, 10 miles, 1000 feet below you. You know approximately where to look in terms of azimuth (left to right), but how far below the airplane is the traffic? The most common mistake I see pilots perform when looking for traffic is exaggerating the up or down component of where they're looking.

At one mile, one degree is 100 feet up or down, so the angle to the traffic is your altitude difference (in 100s of feet) divided by the range in miles. One thousand feet at 10 miles would be 10/10 or one degree down. A finger held at arm's length is about two-degrees wide, so you can see that you won't need to look far down to find this traffic. Traffic at five miles would be two degrees, or a full finger-width. Traffic at two miles would be 5 degrees, or two and a half fingers below your eye level.

As we fly higher, the visual horizon gets farther below the plane extending directly ahead of us. At FL410, the horizon is over three degrees below our horizontal plane. Traffic one thousand feet below us actually appears two degrees above the horizon. We're used to seeing objects above the horizon only if they're above us, so forcing the eye to look up from the horizon requires deliberate thought. In reduced vertical separation minimums (RVSM) airspace, passing traffic with 1000-foot separation is the norm. But at high altitudes it's easy to perceive traffic that is safely below us as being co-altitude and a collision threat. Remember your angles, and you avoid the embarrassment of a panicky pull up to avoid traffic a safe thousand feet below. *—N.S.*

too far down and your display will be filled with ground clutter. Either way, you may not see a large cell until you're nearly on top of it.

What we'd like to do is scan at about the freezing level, or even a little higher, where liquid moisture is raised by updrafts, but has not frozen. Depending on surface temperature and lapse rate, this optimal altitude can vary quite a bit, but using 18,000 feet will generally give satisfactory returns.

Using our knowledge that one degree across 10 miles will fall 1000 feet, we can derive that optimal tilt equals the difference between aircraft altitude and 18 (in thousands of feet), divided by the range at which we're scanning (in tens of nautical miles). Back to our Mustang at FL410, scanning out 80 miles, we'd compute 41-18 (thousands of feet) = 23. Divide 23 by eight (80 miles/10) and you get 2.875. In your head, though, you could say that it's going to be darn close to three degrees tilt down.

For maneuvering in the terminal area at 3000 feet, and scanning out a more tactical 20 miles, we would tilt (3-18)/2 or 7.5 degrees up. If the thought of doing math on negative numbers gives you the heebie-jeebies, you can make it (18-3)/2 and just remember you're tilting up or down to see 18,000 feet relative to your current altitude.

All modern radar is pitch stabilized, so there's no need to compensate for aircraft pitch attitude; the radar will maintain desired tilt relative to the zero-degree plane, not the aircraft nose.

Once we detect that boomer, we need to avoid it. You may remember the written test question that wants pilots to avoid thunderstorms by at least 20 miles, or about 120,000 feet. Great, but airplanes don't turn in nautical-mile increments, they turn in degrees.

Back to one-in-60, we use the same relationship that determined optimal tilt, and turn the triangle from the vertical to the horizontal plane. If we see a cell 80 miles ahead, and wish to pass it by 20 miles laterally we need to turn: 120 (20 miles in thousands of feet)/8 (80 miles in 10s of miles). That works out to 15 degrees past the edge of the return. Considering that most small radar dishes aren't very accurate beyond 80 miles, and that the cells are often five-degrees wide from center to edge, you can see why "Request 20 degrees left" is common in the summer.

The same process can be used to facilitate base-leg entries on visual approaches. A one-mile final is a nice distance to have one last chance to nail descent path and airspeed. So if we're approaching a towered airport VFR, and anticipate receiving instructions to enter a base leg, we can turn left or right from our direct heading by six (one nm in thousands of feet) divided by the range to airport in 10s of miles.

Turning three degrees from direct while 20 miles out will roughly set up for a one-mile final. This ranks much higher on the finesse scale than radical maneuvers in the traffic pattern. For the truly anal-retentive, remember that your direct heading was to the airport reference point, not the threshold, and you may need to add a degree or two to compensate for runway length.

Math Still Matters

Not everyone has a fist-full of computers in their cockpit to speed calculations. And even with all the fancy avionics, there's still plenty of room for some mental math to get the job done when you can't be bothered with a bunch of button pushing.

No one says you have to remember all these figures, but you can copy them down onto a cheat sheet and pull them out when you need them. That'll keep the bad memories of cramming for a math test at bay.

Neil Singer is the Northeast training manager for AirShares Elite and a former airline pilot.