M3

The Mile
The Mach
The Minute

Mental Math for Aviators
Ditch the Calculator

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CHAPTER 1

THE BASICS

1.1 The nautical mile and a little bit of history:

The earth is far from being a perfect sphere. It is flat at the poles, fat at the equator, with uneven terrain over all continents. Finding a useful common reference for distance—and thus speed—was therefore essential in developing a workable model that would fit the intended purpose, and unify navigation distance units worldwide.

The nautical mile (NM) is a unit of length of about **one minute of arc** over any meridian or the equator (great circle). But this was not sufficient to obtain a consistent number since the measurement along the equator would give 1855.4 m, and along a meridian it would give between 1843 m near the equator (zero latitude) and 1861 m near the poles.

In 1929, the International Extraordinary Hydrographic Conference held in Monaco defined one international nautical mile as **1,852 m** exactly, as illustrated in the following figure.

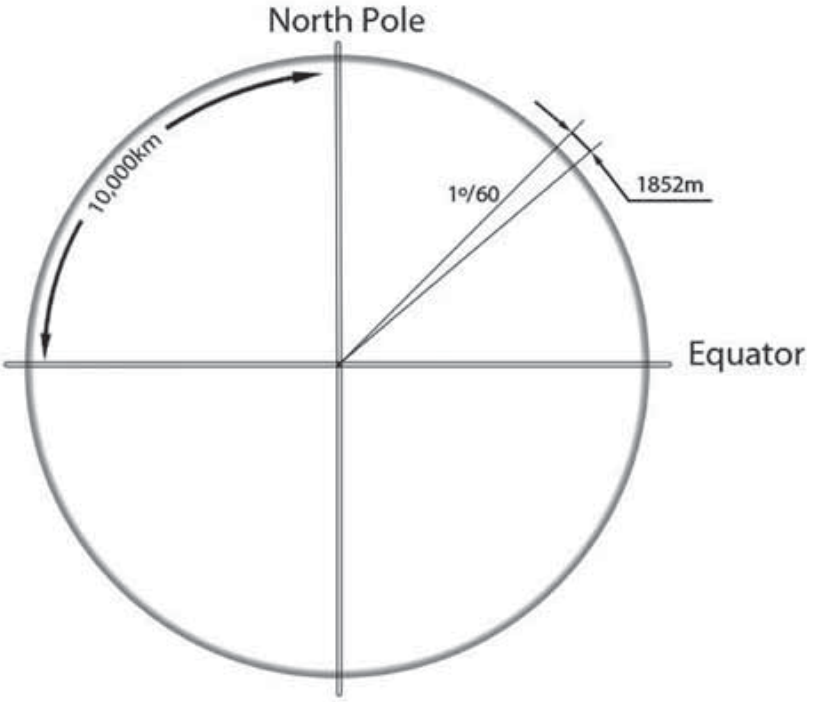

Figure 1.1

1.2 The 1 in 60 rule (or 60:1):

This rule of thumb is incredibly powerful in the aviation environment. It states that for each degree off (or displacement) over a distance of 60 NM, it will result in 1 NM off course. It can be applied in various areas of interest when flying, and is easily remembered.

We will see in other chapters how this rule can be used in many different scenarios, en route navigation, approach, and even on vertical profiles, but let's start with an example:

A pilot tracking a VOR radial outbound has drifted by 1°. If the pilot remains 1° off course while continuing the flight, it can easily be assessed that there will be a drift of 0.5 NM by 30 NM out, 1 NM by 60 NM, 2 NM by 120 NM, and so on. It's a really simple rule.

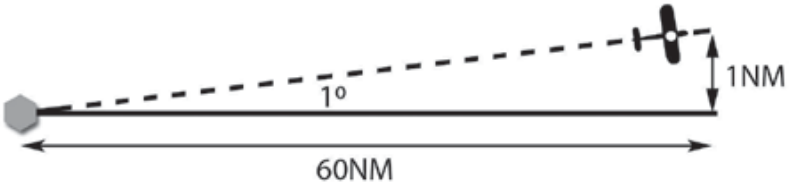

Figure 1.2.1

The math behind this shows that this method is not entirely accurate, with roughly a 5% error, but the aim here is to get *workable* numbers in a dynamic environment, and it fits this purpose quite well.

Here is the breakdown:

A circle of 60 NM radius has a circumference of:

2x60xΠ = **376.99 NM**

If we divide 376.99 by 360° we get:

376.99/360 = **1.047 NM** (off by 4.7%)

We can consider this rule a very good approximation.

As a coincidence, 1 NM is about 6,000 feet (6,076.1 feet) so we can use the 60:1 rule for this too. For a **1 degree shift at 1 NM, there are about 100 feet of offset**.

This becomes very useful for estimating or correcting vertical speed settings and flight path angles (FPA) during climb, descent, or approaches. We'll get back to this.

- **6000'/60 = 100'**

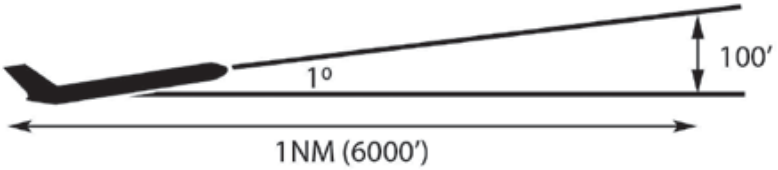

Figure 1.2.2

If a gradient in % is required, the numbers work out with the same rule:

- **1% over 1 NM ≈ 60'**

It is also useful to find out the lateral deviation from a given VOR course or radial: Each dot on a VOR indicator represents 2° of deviation, or **200' per dot per DME**.

There are other applications to this rule. One such application is **time drift.**

An hour is equal to 60 minutes, and a minute is equal to 60 seconds, so some other relationships between angle and time can be observed as described below.

A drift of 1° during 1 hour will result in 1 minute off-track at constant speed.

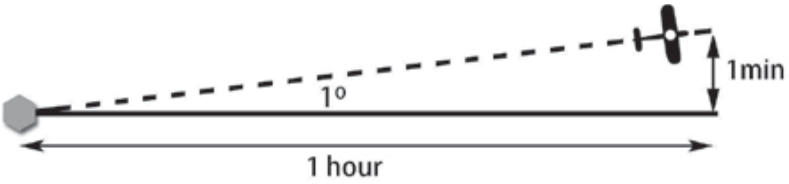

Figure 1.2.3

A drift of 1° during 1 minute will result in 1 second off-track.

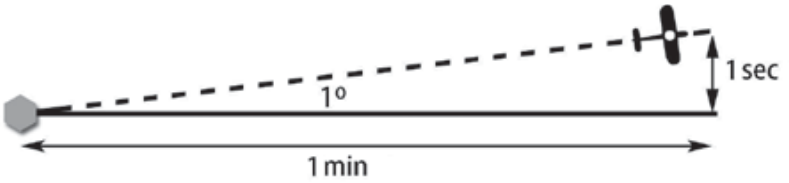

Figure 1.2.4

A drift of 4° during 5 minutes will result in 20 seconds off-track.

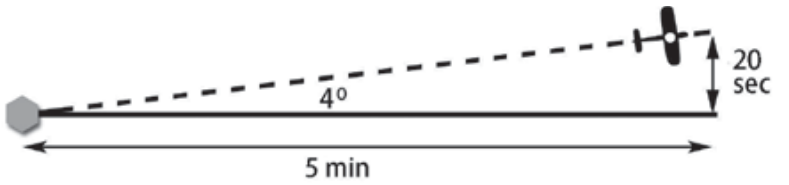

Figure 1.2.5