

1.3 Speeds and time:

Every day, pilots have to deal with different types of speeds. There is enough documentation through exam books and aviation training to properly describe them. However, we can look into some of the most commonly used speeds in everyday operations, and their significance.

One key factor in developing fast mental math is to know speed units, various conversions, and when one unit is more relevant than another based on the results sought or the phase of flight. For example, TAS (true airspeed) would be most appropriate as a base to find a drift angle in cruise, while a Mach number is of no practical use at lower speeds and lower levels. With regular practice, the pilot will become increasingly comfortable playing with numbers. Let's start.

1.3.1 Speed in miles per minute:

- 1 knot is 1 NM/hr.
- 1 hour counts 60 minutes.
- 60 kt is therefore 1 NM per minute (60 NM divided by 60 minutes, later noted as **MPM**).

60 kt	=	1 MPM
120 kt	=	2 MPM
180 kt	=	3 MPM
240 kt	=	4 MPM
300 kt	=	5 MPM
360 kt	=	6 MPM
420 kt	=	7 MPM
480 kt	=	8 MPM
540 kt	=	9 MPM
600 kt	=	10 MPM
and so on...		

It is crucial to remember the list above, as we will use it in a number of situations described later in this book.

As we have seen in the previous section, 1 NM is about 6000', and 1 minute is 60 seconds. The 60:1 rule can be used here as well to find that **1 MPM $\approx$ 100 feet per second (fps)**. When flying to an unpublished airfield, if there is a doubt about the runway length, a flyby at constant speed may help determine the approximate length of the strip. Time the flyby, then convert to feet.

1.3.2 Speed of sound and Mach number:

The speed of sound, indicated as ***a***, or local speed of sound (LSS), is the speed of transmission of disturbances traveling through a medium. For us, this medium will be the air or atmosphere, and the reference will be the true airspeed, or TAS. The air is considered an ideal gas, so the main reference to determine the speed of propagation will be the absolute temperature in Kelvin (K).

The results can be obtained either in knots or meters per second, as follows:

- $39\sqrt{K} = \mathbf{a}$ (in knots)
- $20\sqrt{K} = \mathbf{a}$ (in meters per second)

More exact values for these formulas are respectively 38.94 and 20.03, but the errors with the rounded values are just one knot or so, and are negligible in daily operations.

Absolute zero, or zero Kelvin, is about -273°C. So we have to add 273 to the ambient air temperature displayed in Celsius.

Example 1:

OAT **20°C** = 20 + 273 = 293 K

$39\sqrt{293} = \mathbf{667\ kt}$

$20\sqrt{293} = \mathbf{342\ m/s}$

Example 2:

$$\text{OAT } -25^{\circ}\text{C} = 273 + (-25) = 248 \text{ K}$$

$$39\sqrt{248} = \mathbf{614 \text{ kt}}$$

$$20\sqrt{248} = \mathbf{315 \text{ m/s}}$$

So with $\Delta\text{ISA} \pm 0$, we have:

- at sea level ($+15^{\circ}\text{C}$) $a \approx \mathbf{660 \text{ kt}}$
- at 25000 ft (-35°C) $a \approx \mathbf{600 \text{ kt}}$
- at 34500 ft (-54°C) $a \approx \mathbf{576 \text{ kt}}$

As we can see, the results found are too difficult to figure out without a calculator, so there is a third option that can be worked out mentally in a matter of seconds:

$$\mathbf{LSS \text{ (in kt)} \approx 643 + (1.2 \times T^{\circ} \text{ in Celsius})}$$

Here is how this one works:

Starting with 0°C (that's 273 K) we find that LSS is:

- $38.94\sqrt{273} = \mathbf{643 \text{ kt}}$ at 0°C
- $38.94\sqrt{263} = \mathbf{631 \text{ kt}}$ at -10°C
- $38.94\sqrt{253} = \mathbf{619 \text{ kt}}$ at -20°C
- $38.94\sqrt{243} = \mathbf{607 \text{ kt}}$ at -30°C
- $38.94\sqrt{233} = \mathbf{594 \text{ kt}}$ at -40°C
- etc.

We can easily see that for every 10°C difference, there is about 12 kt change in the LSS. That is 1.2 times the temperature difference. This is shown in example 3 below. It is reasonably accurate, giving results only 1 or 2 kt off.

Example 3:

$$\text{OAT } -25^{\circ}\text{C} \approx 643 + (1.2 \times [-25]) = 643 - 30 = \mathbf{613 \text{ kt}}$$

$$\text{OAT } -40^{\circ}\text{C} \approx 643 + (1.2 \times [-40]) = 643 - 48 = \mathbf{595 \text{ kt}}$$

The Mach number (M) is used as a reference mostly for high-altitude and/or high-speed flight, as the airflow around a given airfoil or aircraft (and configuration) will behave in much the same manner for a given Mach number—other variables left aside. M 1.0 represents the speed of sound in given conditions—temperature, pressure, and fluid characteristics. M 0.81 represents 81% of the local speed of sound, as an example.

Since the speed of sound varies with temperature, two aircraft flying on the same route with the same Mach number but at significantly different altitudes—and thus temperatures—will have different true airspeeds. For example, consider aircraft A at 25,000' (-35°C) at M 0.80 and aircraft B at 35,000' (-54°C), also maintaining M 0.80. Yet they would have a TAS difference of about 20 kt.

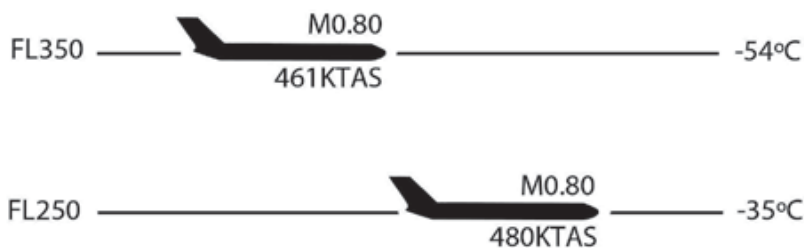


Figure 1.3.2

- 5°C difference $\approx$ 6 kt difference in **a**, or 1%
- 10°C difference $\approx$ 12 kt difference in **a**, or 2%
- 20°C difference $\approx$ 24 kt difference in **a**, or 4%

The opposite is also true: If two aircraft maintain identical TAS or IAS, the one with a higher FL will have a higher Mach number.

1.3.3 Time units:

While converting minutes into tenths is only marginally useful, it can be observed that the same rules apply there, too. After becoming proficient with the 1-in-60 rule and MPM conversions, changing minutes to tenths—or the opposite—will become effortless.

1.4 Angles:

Pitch attitude, angle of attack, bank angle, drift angle, radials, bearings, and descent gradients are among the essential factors that pilots have to deal with on every flight.

With sound reasoning and a bit of practice, dealing with angles in everyday operations will become second nature. We will also see later how to put the calculator away when working with sine and cosine, such as when looking for headwind or crosswind components.

Many examples in the following topics refer to the use or the conversion of speed to nautical miles per minute, indicated as **MPM**, to work with angles. The proficient pilot needs to make sure this concept is fully understood and memorized, in order to take the best advantage and speed up the mental process.

Let's review a few key elements:

- **1 minute of arc** of a great circle $\approx$ **1 NM** ($1/60^{\text{th}}$ of a degree)
- 1 NM $\approx$ 6,000 ft
- 1 degree over 1 NM $\approx$ 100 ft (3 degrees over 1 NM $\approx$ 300 ft, i.e. glide slope)

- 1 degree over 20 NM $\approx$ 2,000 ft (e.g., when using radar tilt to detect weather)
- 2,000 ft to lose over 5 NM is 400 ft/NM $\approx$ 4° slope
- 1° pitch change in flight at 120 kt will result in a rate change of 200 fpm (1° over 1 NM $\approx$ 100ft, so if we fly at 2 MPM, we get 2 x 100 fpm.)
- A 3° glide slope flown at 120 kt will result in 600 fpm rate of descent (120 kt = 2MPM, 3° $\approx$ 300 ft/NM so 2 x 300 = 600 fpm).
- For a standard 3° slope, it may be easier to take half the ground speed and add a zero. For example:
 - 80 kt $\approx$ 80/2 = 40 $\approx$ 400 fpm
 - 100 kt $\approx$ 100/2 = 50 $\approx$ 500 fpm
 - 140 kt $\approx$ 140/2 = 70 $\approx$ 700 fpm

We will deal with larger angle values later, when we work with wind and wind components.

1.5 Conversions:

1.5.1 Temperature conversions:

The Fahrenheit scale is still used today in the United States and a few other countries. The rest of the world is using the Celsius scale, or centigrade. The formula to convert one to the other is cumbersome, and hardly usable without a calculator, so we'll look at some other options, with varying degrees of accuracy.