Basic **Navigation** Concepts

Skill Level: ***Basic***

Category: Navigation

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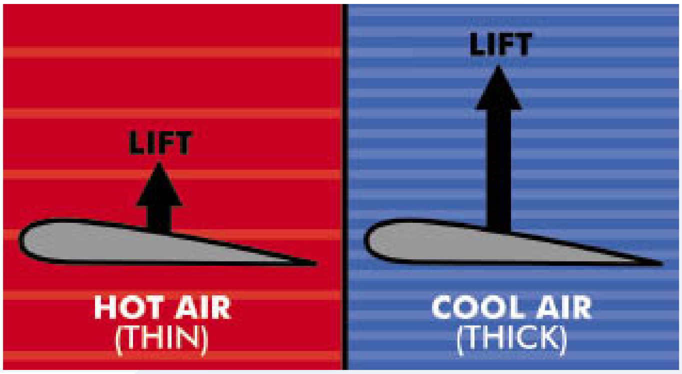
Do you know that the Airspeed Indicator does not indicate your true speed through the air, or that the compass does not indicate your true direction? All is not what it seems, what you see may not be what you get in aviation science. Let us now take time to study some of these peculiarities as we introduce some of the Basic Navigation Concepts.

The International Standard Atmosphere

It sounds like a contradiction of terms; the fact that such a fluid, dynamically changing entity such as the very air we breathe could be globally standardised. It is quite obvious even to the layman that the atmosphere is hotter in summer, cooler in winter, and that you are more likely to freeze to death at the poles than at the equator. We need some average, some benchmark or standard that we can relate current conditions to. Enter the International Standard Atmosphere or ISA.

So why all the fuss about trying to standardise the atmosphere? The answer is in the way atmospheric conditions affect the flight of our aircraft. In short, warm air expands and therefore becomes less dense. The amount of lift produced by a wing is directly dependent on the density of the air through which it travels. For a given speed, a wing travelling through a parcel of hot (and therefore less dense) air will produce less lift than the same wing travelling at the same speed through relatively cool air.



Temperature affects density, which in turn affects the amount of lift generated

Secondly, we know that air pressure reduces with altitude. This is a natural consequence of the effect of gravity on the air molecules. Closer to the earth the weight of the air above causes the pressure to be relatively high, while the higher we go, the lower the pressure of the ambient air.

Pressure reduces with height.

Further to this, as we learned in the previous article, variations in sea-level pressure occur as a result of the global circulation, resulting in the areas of 'High' and 'Low' pressure you are familiar with on the nightly weather map. So, it is possible for an aircraft at a constant altitude to experience changing atmospheric pressure when flying from one pressure area to another.

To provide a reference set of conditions to which we can relate the changing atmospheric conditions, there exists an International Standard Atmosphere with the following stated conditions:

International Standard Atmosphere	
Pressure (at sea level):	29.92 inHg (Inches of mercury) or 1013 hPa (Hectopascals); and
Temperature (at sea level):	59° F (15°C)

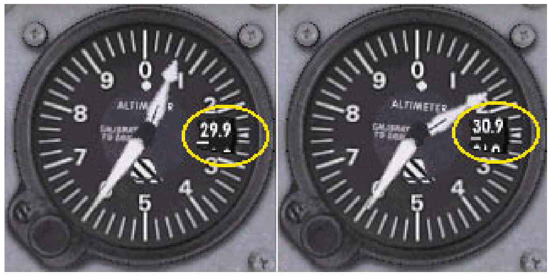
Effect of Altitude on Pressure and Temperature

Temperature and pressure both reduce with altitude: Temperature at the rate of 3.5°F/1000 ft (2°C/1000 ft) and pressure at the rate of 1 inHg per 1000 ft (1 hPa per 30 ft).

Altitude	Temperature	Pressure
Sea Level	59°F (15°C)	29.92 inHg (1013 hPa)
1000 ft	56°F (13° C)	28.92 inHg (980 hPa)
4000 ft	45°F (7° C)	25.92 inHg (880 hPa)
9000 ft	28°F (-3° C)	20.92 inHg (713 hPa)

Some approximate values in the ISA. Note the temperature goes below freezing between 4000ft and 9000ft.

You can prove these values in a practical way using Flight Simulator. Set yourself up at Meigs and note the altitude indication with the standard 29.92 in Hg set. You should read 600 feet. Then using the pressure-setting knob, set 1600 feet (ie add 1000 feet to the original reading) on the altimeter. Note the sub-scale setting has increased to 30.92, an increase of 1 inch.



Using the subscale, you can prove that 1000 feet of altitude represents about 1 in Hg.

Next, reset your altimeter to 600 feet. Take note of the outside air temperature to the right of the altimeter (mine shows 59° F, yours could be different depending on the season you have set). Now, open the World|Map View… dialog and in altitude change it to 5600 feet (ie 5000 above Miegs). Make sure you are paused before you do or you will simply drop out of the sky. Now, momentarily un-pause the sim then re-pause it with the {P} key. The Outside Air Temp gauge should refresh to indicate a new temperature (mine indicated 39° F representing a total 17° F drop, or 3.5° F per 1000 feet).

Temperature drop with altitude is obvious when comparing these readings 5000 feet apart.

Pressure Altitude

Any discussion regarding aircraft performance must consider the current ambient atmospheric pressure. Low pressure and therefore thinner air results in a reduced lifting capability, this could mean the aircraft has insufficient runway available for take off. To simplify calculations of aircraft performance, flight manuals generally table the values of runway length required, landing distance required, climb performance, etc against altitude in the ISA. This ISA altitude is referred to as Pressure Altitude.

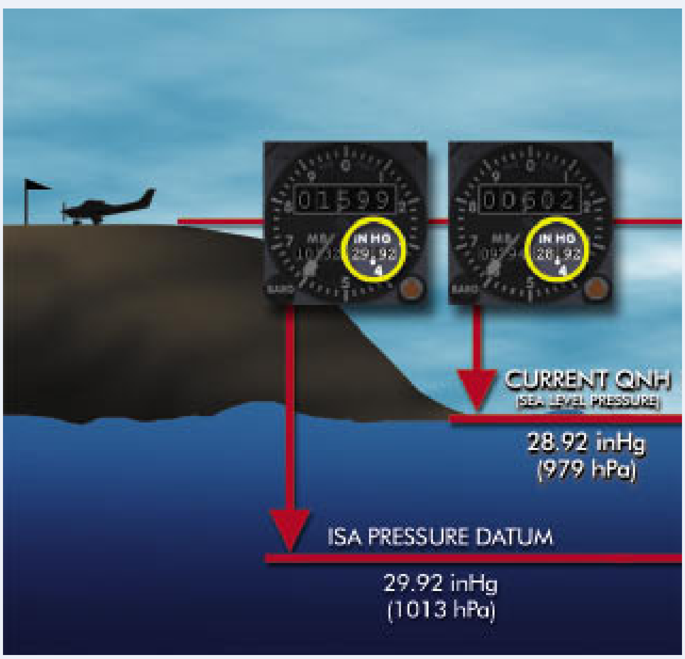
Pressure Altitude is the current altitude adjusted for the difference in sea-level pressure from the ISA standard of 29.92 in Hg (1013 hPa).
For example, consider an aircraft siting on a runway 600 feet above mean sea level (AMSL). Now, lets say the sea-level pressure (referred to as QNH) is not 29.92 in Hg, but is something lower. We are in an area of Low pressure perhaps. The aircraft's Pressure Height (its altitude in ISA) will be something higher than 600 feet. The pressure is lower, so that naturally equates to a higher altitude.

Let's say the current QNH (sea-level pressure) is 28.92 in Hg (1 in Hg lower than ISA) or 979 hPa (34 hPa lower than ISA). The 1 inHg less than standard 29.92 inHg means that the aircraft will be 1000 feet higher in the ISA. 1 inHg represents 1000 feet of altitude.

You can demonstrate this effect yourself. Set up your aircraft at Meigs Field and note your altitude reads 600 feet with the pressure setting of 29.92. Now, change the sea-level pressure to 28.92 using the **World|Weather|Advanced Weather…** option. In the **Temp/Pressure** tab change the pressure at sea level to 28.92 as shown here.

Setting the pressure to 28.92 inHg at Meigs.

Now, when you return to Meigs, your altimeter (which is still set to 29.92) will over read your actual altitude by 1000 feet. It is now actually reading your Pressure Height in ISA (ie based on the 29.92/1013 pressure datum). Your pressure height at Meigs is 1600 feet, so you can expect the aircraft to perform as if it was at 1600 feet, not the actual 600 feet! This may be critical in a large transport aircraft.



Here's the theory behind our two indications. One is based on actual QNH the other set to 29.92 represents the pressure height.

If you ever need to determine your Pressure Height, simply dial up 29.92 on the altimeter sub-scale to read Pressure Height directly. Don't forget to return the setting to the original QNH to avoid a nasty error in reading your true altitude.

True Airspeed verses Indicated Airspeed

I'm sure you're familiar with the term; "What you see is what you get". That statement, while often a good general rule, hopelessly breaks down when we deal with the science of aviation. One area where things go a little 'weird' is in the measurement of our speed through the air. Armed with the knowledge of the International Standard Atmosphere let's explain the peculiarities of the Airspeed Indicator and its relationship to True Airspeed.

With a few cents and a few old household items you can make a fairly accurate Airspeed Indicator. Hammer a nail into a plank of wood as a hinge, then bend the handle of an old spoon around the nail. Allow the spoon to tilt under the effect of the airstream as you drive your car at predetermined speeds. Mark each speed with a pencil and there you have a basic Airspeed Indicator.

Airspeed Indicator Mark I - The airflow moves the spoon allowing you to read off air speed.

While I certainly don't want you to go to the trouble of making it, the spoon ASI teaches us a valuable lesson. You can be assured that the spoon ASI will give you reasonable accuracy as long as the atmospheric conditions are the same as when you 'calibrated' the instrument. You did this when you drove along and marked the wood by reference to the car's speedometer.

> ***"With a few cents and a few old household items you can make a fairly accurate Airspeed Indicator"***

Firstly, you made sure that there was no wind otherwise your calibration will contain an inbuilt error. Into a 5 mph headwind for example, your zero position (car at rest) would have you mark the 0 mph line with the spoon slightly displaced from the vertical. Every mark you make will be in error by 5 mph (the value of the head wind).

So, rule one is:

Airspeed is the speed through the air, not over the ground.

Now, take your spoon ASI out on your ski boat. Motor along at 5 mph and note the reading on the spoon. No doubt, due to the thickness of the water, your spoon will be at full deflection, over reading completely. You are using the spoon ASI in conditions other than those that existed when the unit was calibrated.

The density of water is abundantly greater than the conditions used during the calibration: The spoon ASI over reads.

Finally, take your spoon ASI to the top of Mt Everest where in the rarefied atmosphere you will require breathing apparatus just to stay alive. Now, as you move forward at 10 mph your ASI will show perhaps 3 mph. The thin air, while moving past the spoon at 10 mph, is so thin that it does not have the energy to displace the spoon as far as it did at sea level; the instrument now under reads.

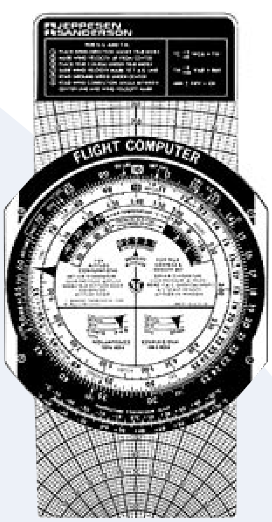
The thinner air at 29,000 ft causes our spoon ASI to under read.

The garden variety ASI in the Cessna 182 - and in most general aviation aircraft for that matter - is pretty similar to our humble spoon ASI. The principle is basically the same in that it measures the force generated by the airflow, not the actual speed of the air passing through the instrument. Just as the spoon ASI will under read on Everest so to will the Cessna's ASI.

Again, it comes down to calibration. You calibrated the spoon ASI in the car with a set of conditions. The ASI was calibrated to conditions of sea level in the ISA (International Standard Atmosphere). Any variation from ISA at sea level (ie 29.92 in Hg and 59°F) will cause an 'error' in the displayed speed. Generally, this will be an under reading error. The indicated speed will be less than the true speed when the aircraft is at an altitude above sea level and/or in warmer air.

I say 'error' in inverted commas because it really is not an error. Indicated Airspeed is a valuable reading in its own right; Indicated Airspeed (IAS) is in direct proportion to the energy in the airstream, and it is this energy that governs the amount of lift that will be produced. IAS tells us how well the aircraft is flying. If it is low, then we are at risk of stalling, if it is high then the drag on delicate aircraft components may be approaching dangerously high levels and we may have to slow down. Hence, IAS is the preferred indication in the cockpit; it tells us how much energy we are dealing with and the handling of the aircraft will be the same for a given IAS.

True Airspeed (TAS) is the true speed of the aircraft through the air. For navigation, this is a speed we need to know. As pilot's we generally obtain TAS by setting the values of temperature and pressure altitude on a flight computer. These handy devices don't require batteries and are always handy for performing in-flight calculations. To give you some idea of the values of TAS for a given IAS refer to the table below.



One example of a pilot's flight computer. Smaller versions are available that fit in your shirt pocket.

Altitude	ISA - 20°F	ISA	ISA + 20°F
Sea Level	147	150	153
5000 feet	158	161	164
10000 feet	171	174	178

TAS values for an IAS of 150 knots at varying altitudes and temperatures.

Notice in the IAS-TAS table that at sea level with ISA temperature (59° at sea level) that the TAS equals IAS. These are the calibration parameters for the ASI. Notice also that the greatest effect is changes in altitude; 40° of temperature change gives just 6 knots difference between ISA - 20° and ISA + 20°, while at 10000 feet, TAS has increased 24 knots. You can see why we like to fly as high as possible, to obtain the greatest TAS for a given IAS.

For a practical application, set up the Cessna 182S, depart Meigs and climb overhead to 9000 feet. Then pause the sim when you get there to have your hands free for a brief lesson on True Air Speed.

Try it now ✈

Setting Indicated Airspeed as the default (and more realistic) ASI indication.

Next, under **Aircraft | Realism**… set the display of Indicated Air Speed rather than the default True Air Speed. When you return to the aircraft, note the current indicated airspeed. My aircraft is stabilising at around 120 knots indicated.

Now, under **Options | Settings | International**… select Metric (Altimeter Feet) in the Units of Measure drop-down list. This will allow your OAT thermometer to display the temperature in °C, necessary to correlate the temperature on the TAS dial on the Airspeed Indicator.

Setting Metric to allow the Outside Air Temp (OAT) to display °C.

Obtaining TAS from the Cessna's Airspeed Indicator

A rather handy little optional extra provided on most modern light aircraft is the TAS conversion scale built into the ASI. You will note a white band in the region of the dial at normal cruise speeds. This band is a window that displays the values of TAS based on a setting in the upper window. By setting the current temperature against the current pressure altitude (remember: this is your height above the 29.92 in Hg datum) you can directly read TAS on the ASI.

Let's try it…

Step 1 Note the temperature on the IOAT (Indicated Outside Air Temperature) gauge. My gauge shows 0° C. We have to use Celsius because the TAS setting window is marked in °C.

Step 2 Dial 29.92 on the altimeter subscale to read pressure height. In our case, if you have reset the sim, the current QNH is probably 29.92, so our setting remains untouched. Read the displayed altitude (9000 feet in my case).

Step 3 Set 9000 against 0° C in the TAS setting window of the ASI.

Step 4 Read the TAS directly on the ASI. My gauge shows about 136 knots.

There is a 20-knot difference for the better in my case; TAS is 20 knots faster than the Indicated Air Speed. It just goes to show, cruising at such altitudes does provide a real benefit in performance, the thinner air has allowed the aircraft to move through it 20 knots faster than it would at sea level.

Summary

Its true that what you see is not always what you get, and that was just a brief insight into some of the concepts involved in pilot navigation: TAS, Pressure Height and the International Standard Atmosphere. A thorough understanding of these basic elements is necessary to move forward in our study of navigation in future articles. Until then, enjoy your time with Flight Simulator and remember to keep it as realistic as you can every time you fly.

Keep Flying ✈

Reading TAS directly on the ASI by setting 9000 feet against the outside air temp of 0°C.