VII

CONVERSION & USE OF FLIGHT COMPUTER

(CRP-5)

Temperature

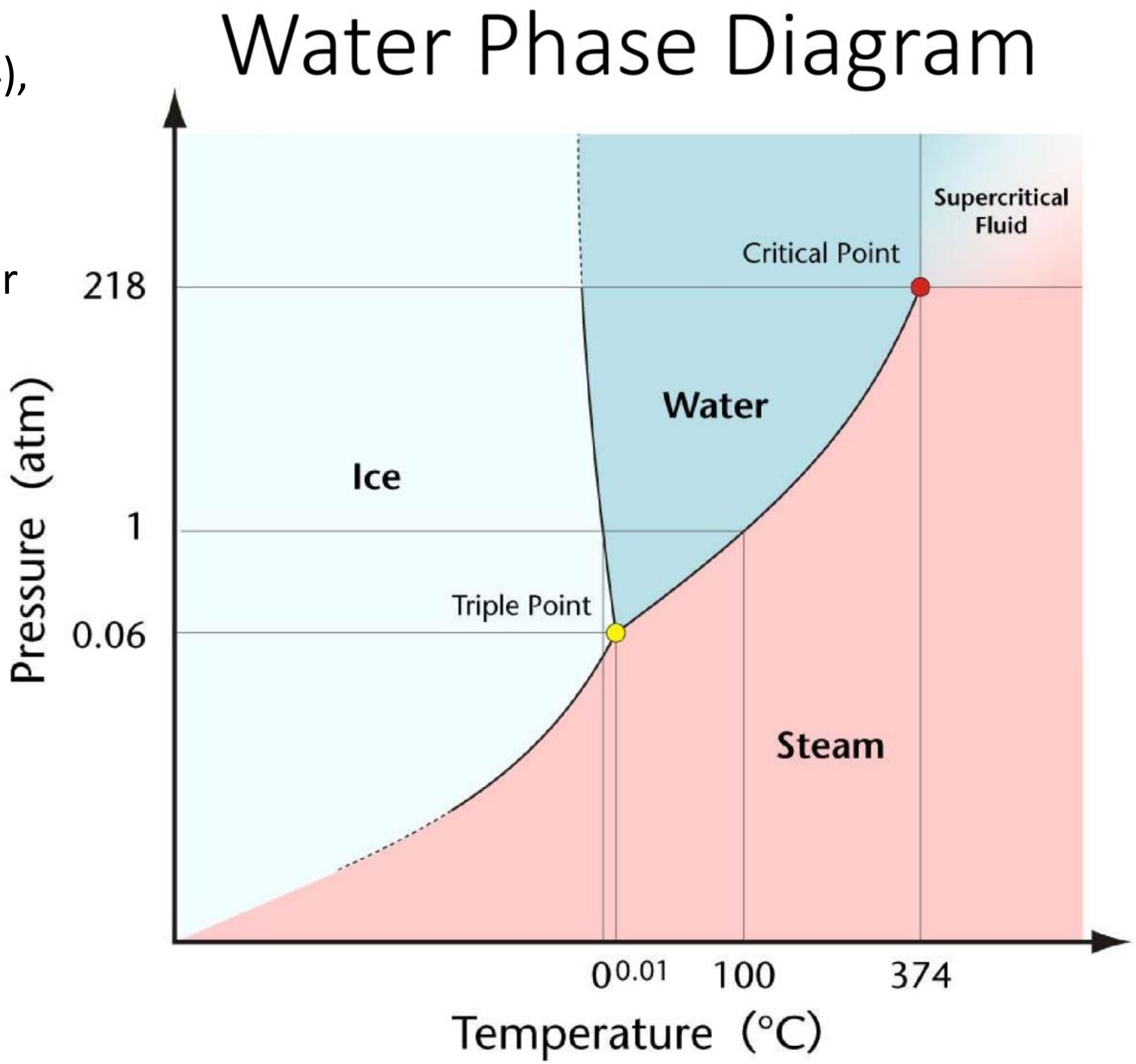
Temperature the measurement of the particles' agitation. The higher the agitation the higher the temperature and vice versa.

Degree Celsius (°C)

named after the Swedish astronomer Anders Celsius (1701–1744), who developed a similar temperature scale. The degree Celsius (symbol: °C)

the Celsius scale was based on 0 °C for the freezing point of water and 100 °C for the boiling point of water at 1 atm pressure.

Anders Celsius (1701–1744)



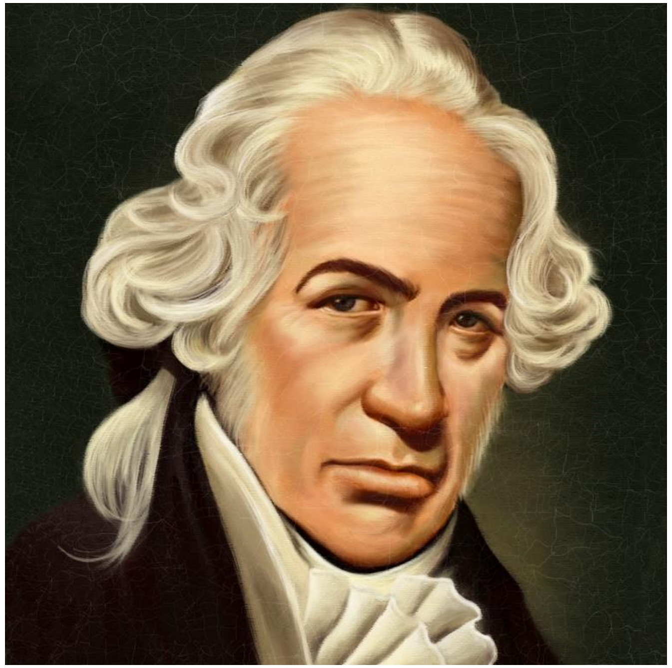
Temperature

Temperature the measurement of the particles’ agitation. The higher the agitation the higher the temperature and vice versa.

Degree Fahrenheit (°F)

The Fahrenheit scale is a temperature scale based on one proposed in 1724 by physicist Daniel Gabriel Fahrenheit (1686–1736). It uses the degree Fahrenheit (symbol: °F)

According to a German story, Fahrenheit actually chose the lowest air temperature measured in his hometown Danzig (Gdańsk, Poland) in winter 1708/09 as 0 °F, and only later had the need to be able to make this value reproducible using brine. The second point, 96 degrees, was approximately the human body's temperature



Daniel Gabriel Fahrenheit (1686–1736)

$$T°F = T°C \times (9/5) + 32$$

$$T°F = T°C \times 1.8 + 32$$

Temperature

Temperature the measurement of the particles' agitation. The higher the agitation the higher the temperature and vice versa.

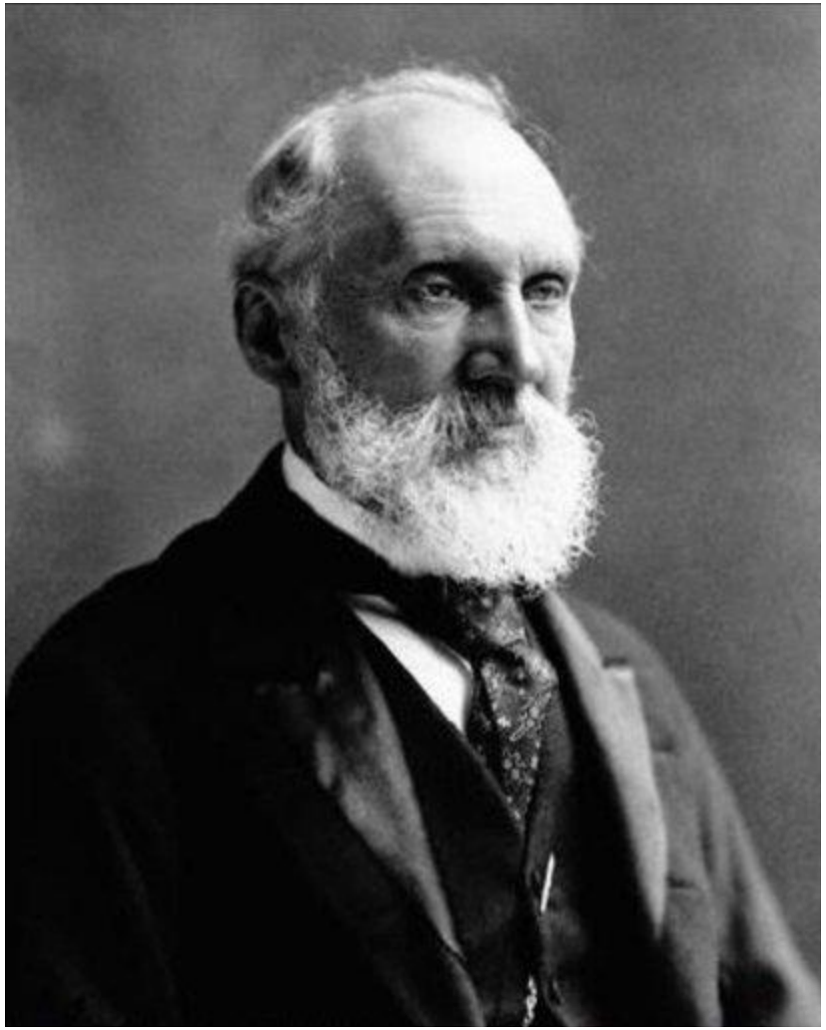
Kelvin (K)

The kelvin is the base unit of temperature in the International System of Units (SI), having the unit symbol K. It is named after the Belfast-born, Glasgow University engineer and physicist William Thomson, 1st Baron Kelvin (1824–1907).

Absolute temperatures are stated in units of kelvin in his honour. While the existence of a lower limit to temperature (absolute zero) was known prior to his work, Kelvin is known for determining its correct value as approximately −273.15 degree Celsius or −459.67 degree Fahrenheit.

$$K = T°C + 273{,}15$$

$$\boldsymbol{K = T°C + 273}$$



William Thomson, 1st Baron Kelvin (1824–1907)

Temperature

International Standard Atmosphere (ISA)

The parameters of the atmosphere (temperature, pressure, density, etc.) are constantly changing. The International Standard Atmosphere has been established in order to have an “ideal” atmosphere for reference.

The parameters in ISA to be known for this lesson and in general are:

In ISA at Sea Level:

T°= 15°C (or 59°F)

Pressure= 1013.25 hPa or 1013.25 mb

(or 29.92 inHg)

Density= 1.225 kg/m³

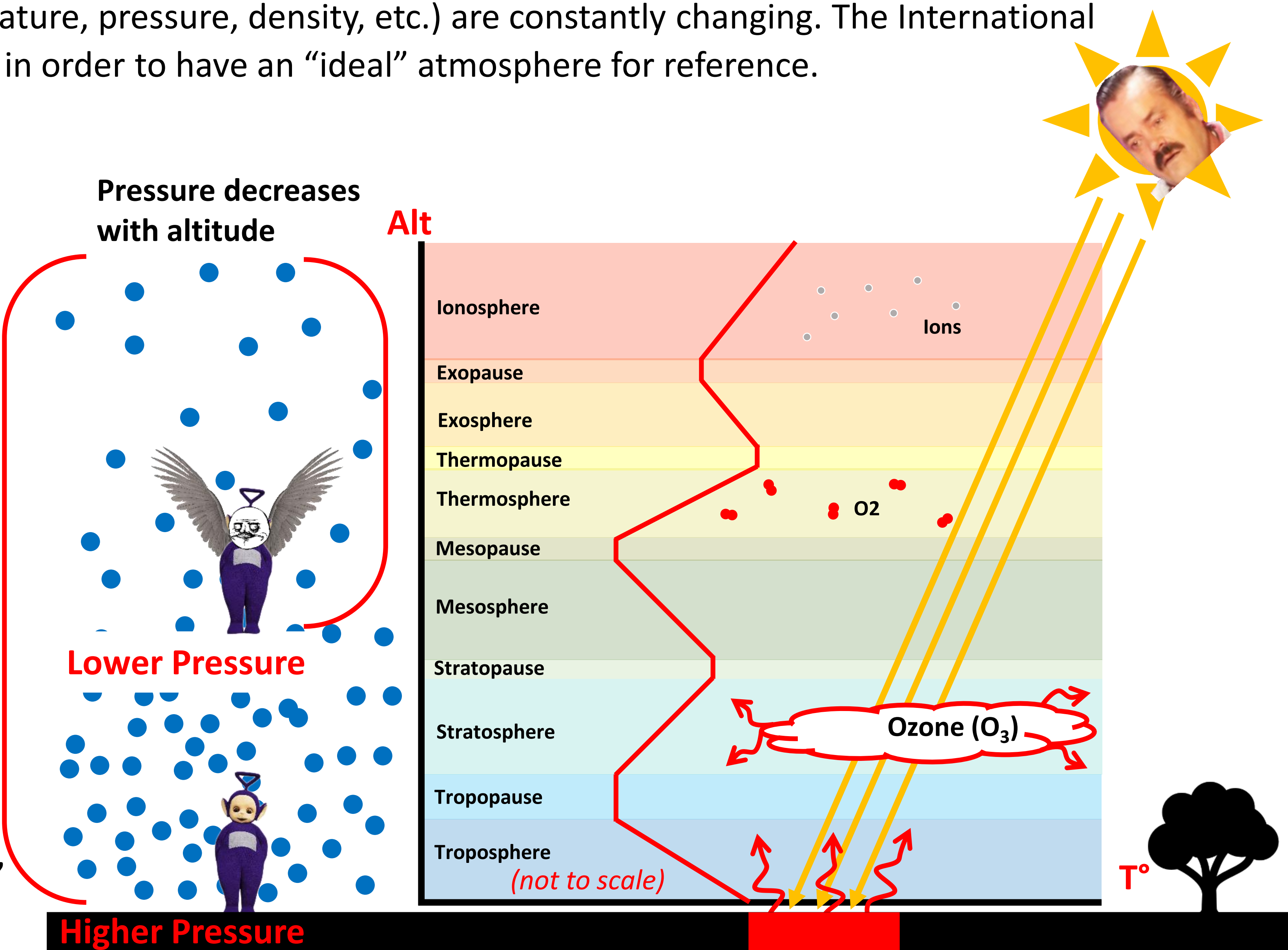
Environmental Lapse Rate (ELR)

-2°C/+1000 ft (or -0.65°C/+100m)

Pressure Lapse Rate (PLR)

-1 hPa/+27 ft [**use -1 hPa/+30 ft**]

In ISA, the tropopause at 11km or 36000 ft, where the temperature is -56.5°C



Temperature

ISA Temperature

The Outside Air Temperature (OAT) in ISA decrease by 2°C every 1000 ft, and it +15°C at Sea Level. To find the temperature at a given Pressure Altitude or Flight Level (FL), we decrease the temperature by 2°C every 1000 ft from +15°C. Remember that at 36000 ft and higher, the temperature doesn’t decrease below -56.5°C.

→ ***Temp ISA (°C) = 15 – (2 x ALT/1000)***

Eg. In ISA, the OAT at FL200 is: ***Temp ISA (°C) at FL200 = 15 – (2 x 20,000/1000) = 15 – 40 = -25°C***

However the atmosphere is rarely standard, so the actual OAT may deviate from the ISA value.

→ ***ISA deviation = OAT - ISA***

Eg. What is the ISA deviation if the OAT is -35°C at FL200 is: ***ISA deviation = -35°C – (-25°C) = -10°***

In this condition, the atmosphere is 10°C colder than ISA, and it written: **ISA-10 (-25 – 10)**

However if it was 10°C warmer than ISA (OAT at FL200 = -15°C), in this case it would be written: **ISA+10 (-25 + 10)**

Eg. What is the OAT at FL250 in ISA+5? ***Temp ISA (°C) at FL250 = 15 – (2 x 25,000/1000) = 15 – 50 = -35°C***

OAT = ISA + ISA deviation = -35°C +5 = -30°C

Temperature Summary

Degree Celsius (°C)
Degree Fahrenheit (°F)

$$T°F = T°C \times (9/5) + 32$$
$$T°F = T°C \times 1.8 + 32$$

Kelvin

$$K = T°C + 273$$

Temperature in ISA

$$Temp\ ISA\ (°C) = 15 - (2 \times ALT/1000)$$

Deviation from ISA

$$ISA\ deviation = OAT - ISA$$

Distance and speed Conversion Summary

1 Nm = 1.852 km
1 Nm = 1.15 Sm
1 Nm = 6080 ft
1 m = 3.28 ft
1 ft = 12 in

1 kt = 1 Nm/h
1 MPH = 1 Sm/h
1 kt = 1.852 km/h
1 kt = 1.15 MPH

Use as approximation:

1 kt ≈ 100 ft/min

$$1\ kt = \frac{1\ Nm}{hour} \approx \frac{6000\ ft}{60\ min} \approx 100\ ft/min$$

1 Nm = 6000 ft

1 m/s ≈ 2 kt

$$1\ kt = \frac{1\ Nm}{hour} \approx \frac{1800\ m}{3600\ sec} \approx ½\ m/s$$

1 Nm = 1800 m

Quantity & Mass

The fuel is measured as a volume when establishing the required of quantity, the common unit used in aviation for the fuel quantity are:

- US Gallon (USG)
- Imperial Gallon (ImpG)
- Litre (l)

According to ICAO Annex 5

1 Imp G = 4,546 l
1 USG = 3,7854 l

However, in order to establish the mass and balance of the aeroplane during flight planning, it is necessary to measure the mass of the fuel. The common unit used in aviation for the fuel mass are:

- Kilogram (kg)
- Pound (lb)

According to ICAO Annex 5

1 kg = 2,205 lbs

Quantity & Mass

To convert a quantity (v) to a mass (m), the density (ρ) of the substance must be known.

$$V \times \rho = m$$

For convenience and to avoid the conflicts between the different units of mass and volume, we convert the volume into mass by using the **Specific Gravity** (**SG**). The Specific Gravity is the ratio between the density of two given fluids. In our case, we will use the ratio between the density of the fuel and the density of the water.

$$SG = \frac{\rho_{fuel}}{\rho_{water}} \leftrightarrow \rho_{fuel} = SG \times \rho_{water} \rightarrow V_{FUEL} \times \rho_{FUEL} = m_{FUEL}$$

$$V_{FUEL} \times (SG \times \rho_{WATER}) = m_{FUEL}$$

1 l of water = 1 kg, so ρ_{WATER} = 1 kg/l
if 1 l of fuel = ‘n’ kg, so ρ_{FUEL} = ‘n’ kg/l

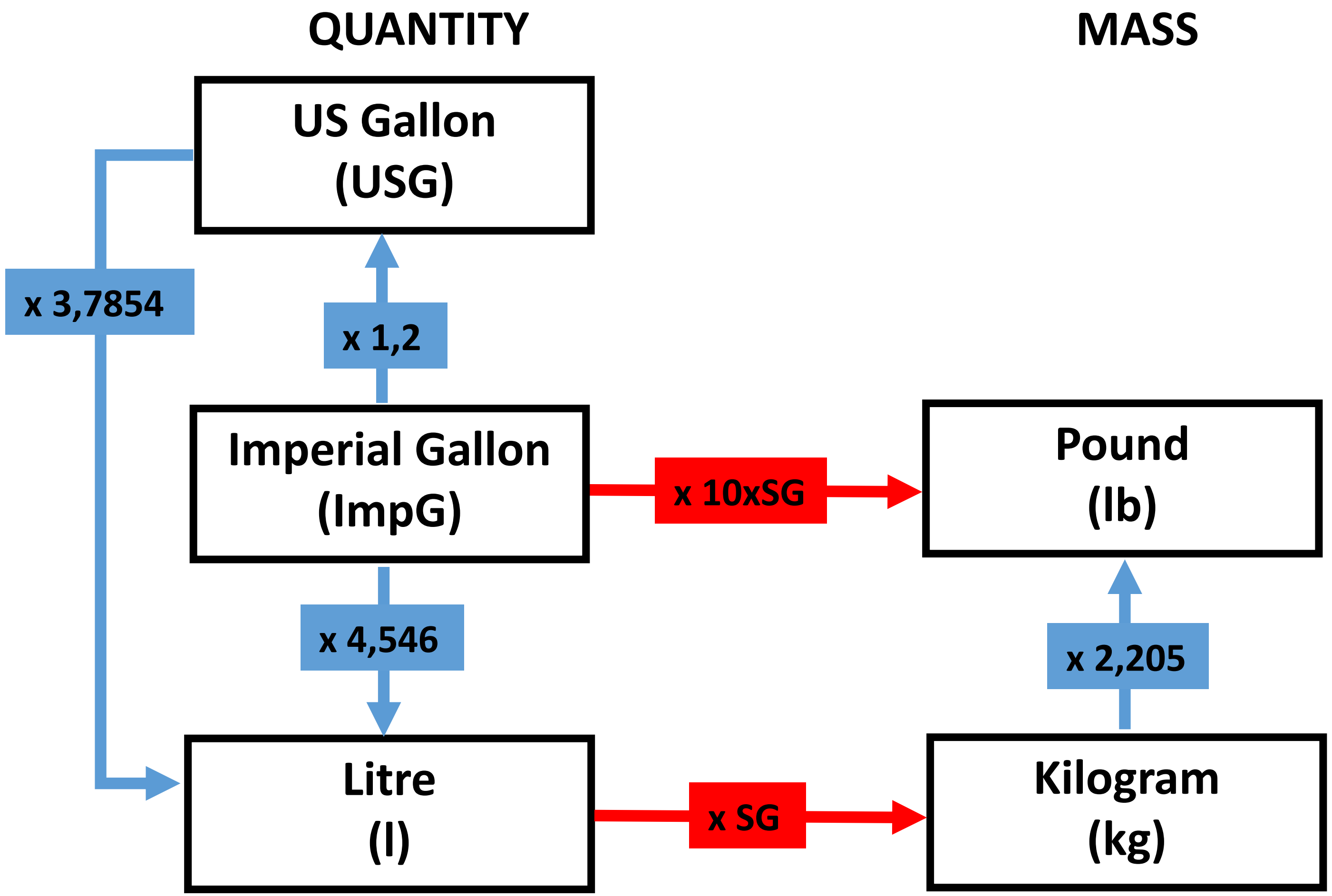
$$SG = \frac{'n'}{1} \rightarrow V_{FUEL}(l) \times (SG \times 1) = m_{FUEL}(kg)$$

$$V_{FUEL}(l) \times SG = m_{FUEL}(kg)$$

1 impG of water = 10 lbs, so ρ_{WATER} = 10 lbs/impG
if 1 impG of fuel = ‘n’ lbs, so ρ_{FUEL} = ‘n’ lbs/impG

$$SG = \frac{'n'}{10} \rightarrow V_{FUEL}(impG) \times (SG \times 10) = m_{FUEL}(lb)$$

Quantity & Mass Conversion Summary



NOTE! A common conversion of AvGas 100LL is: **1 USG of AvGas 100LL ↔ 6 lbs**

Speed Measurement

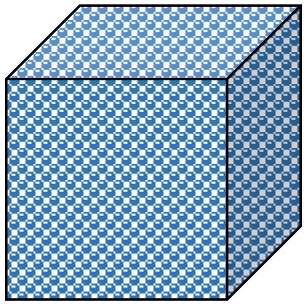
When a particle is in motion, it will have a kinetic energy (**E_K**) that depends on its velocity (**V**) and its mass (**m**)

$$E_K = \frac{1}{2} m V^2$$

For a fluid, its mass is the mass for a given volume ($\boldsymbol{\mathcal{v}}$) of that fluid, so the mass of a fluid is actually its density (**ρ**). So the kinetic energy of the fluid is:

$$E_{K\,fluid} = \frac{1}{2} \frac{m}{\mathcal{v}} V^2$$

$$E_{K\,fluid} = \frac{1}{2} \rho V^2$$



The kinetic energy of the fluid is called the Dynamic Pressure (Q)

$$E_{K\,fluid} = Q = \frac{1}{2} \rho V^2$$

The air being a fluid, so its kinetic energy or Dynamic Pressure depends on its density and real/true airspeed (TAS)

$$Q_{AIR} = \frac{1}{2} \rho (TAS)^2$$

To measure the aircraft's speed, we actually measure the speed of its relative airflow, so the speed of the air mass hitting the aircraft when moving into it. This is why we speak about airspeed instead of speed.

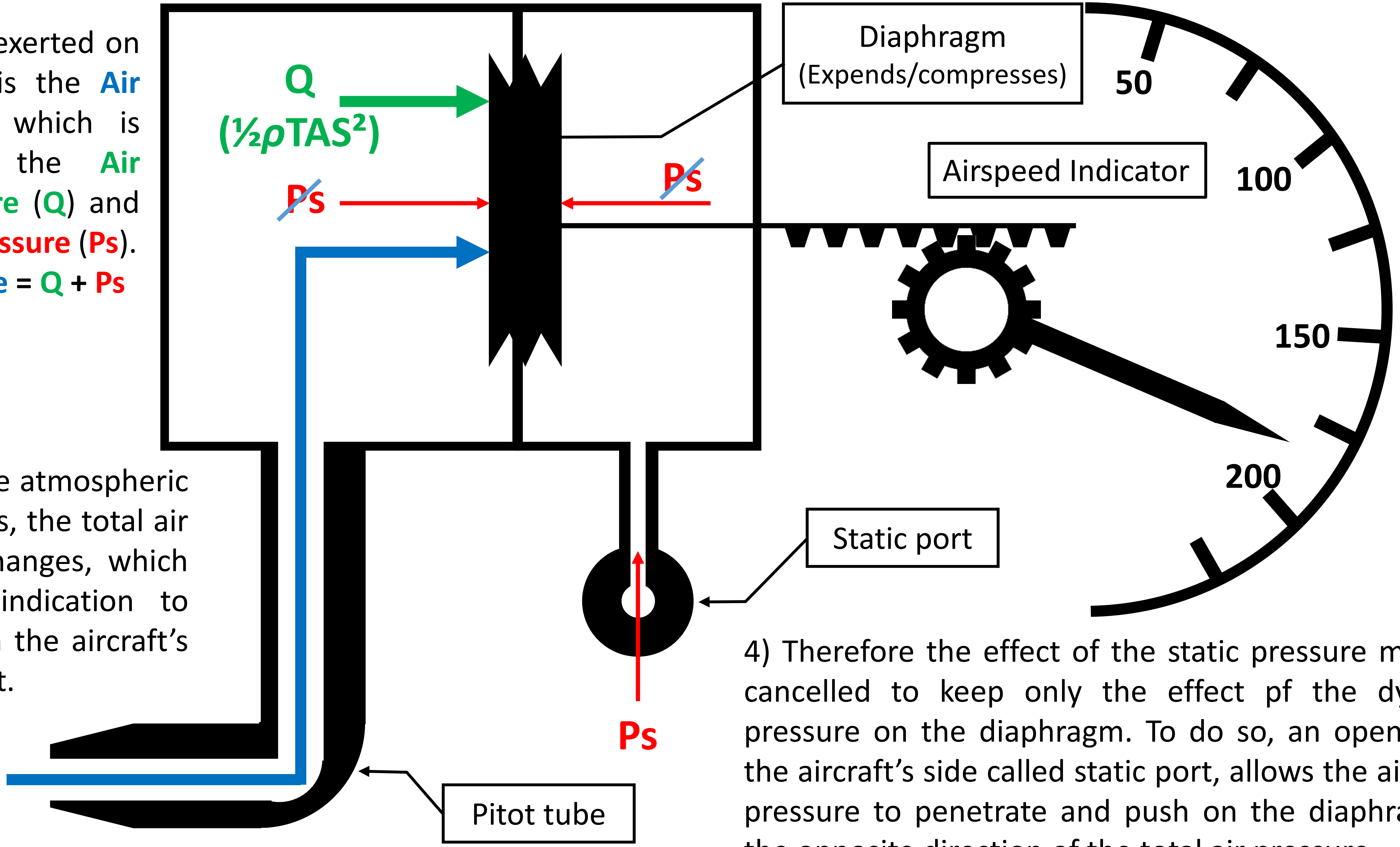
Speed Measurement

Indicated Airspeed (IAS)

1) To measure the airspeed, the air mass enters into the pitot tube, where it will pushed on the diaphragm that will displace the gears of the airspeed indicator to show a value.

2) The pressure exerted on the diaphragm is the **Air Total Pressure**, which is composed by the **Air Dynamic Pressure** (**Q**) and the **Air Static Pressure** (**Ps**).

Air Total Pressure = **Q** + **Ps**



3) However if the atmospheric pressure changes, the total air pressure also changes, which cause to the indication to change although the aircraft's speed is constant.

4) Therefore the effect of the static pressure must be cancelled to keep only the effect pf the dynamic pressure on the diaphragm. To do so, an opening on the aircraft's side called static port, allows the air static pressure to penetrate and push on the diaphragm in the opposite direction of the total air pressure.

Speed Measurement

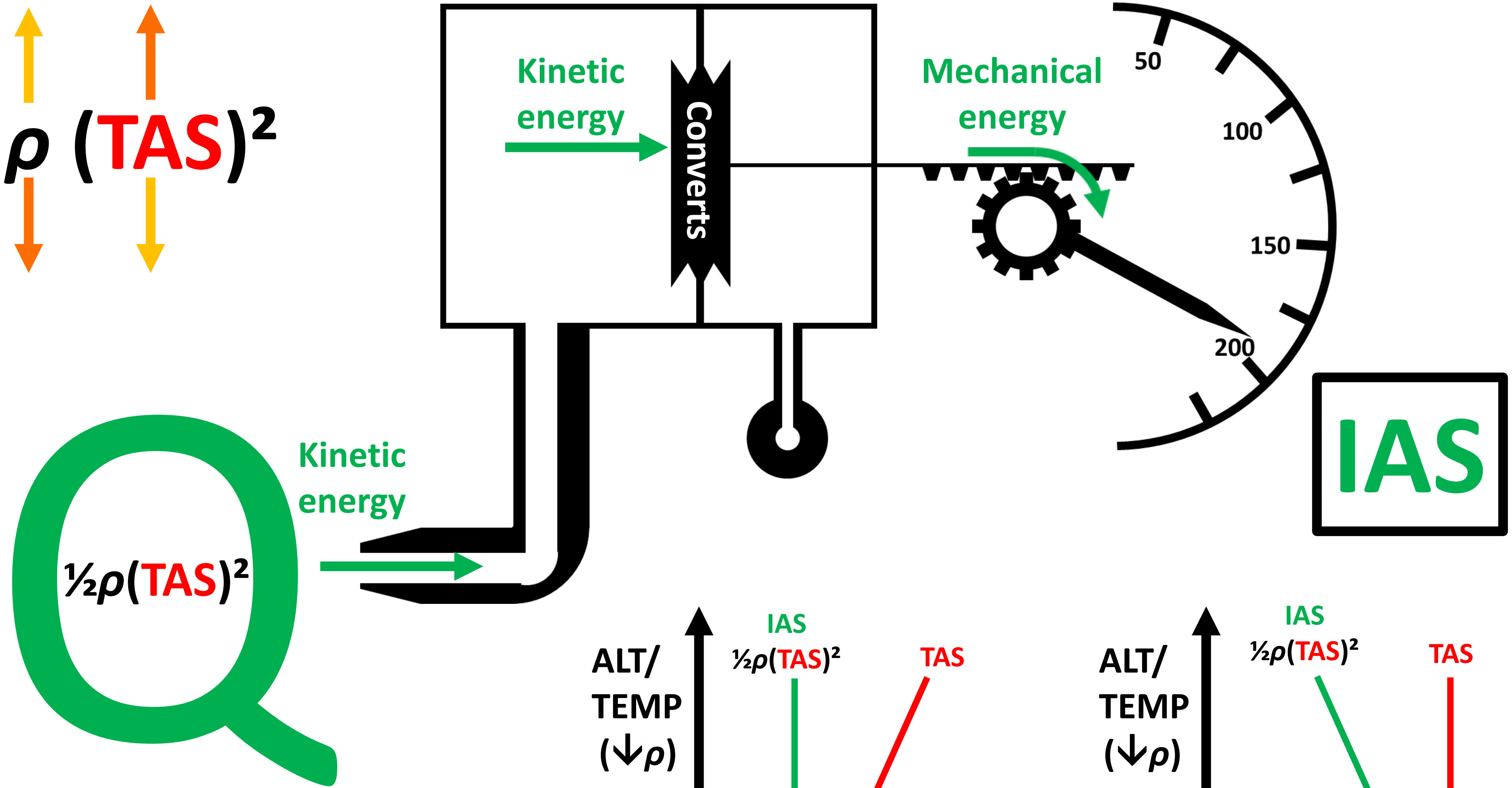
True Airspeed (TAS)

For a constant

$$IAS = Q = \frac{1}{2} \rho \, (TAS)^2$$

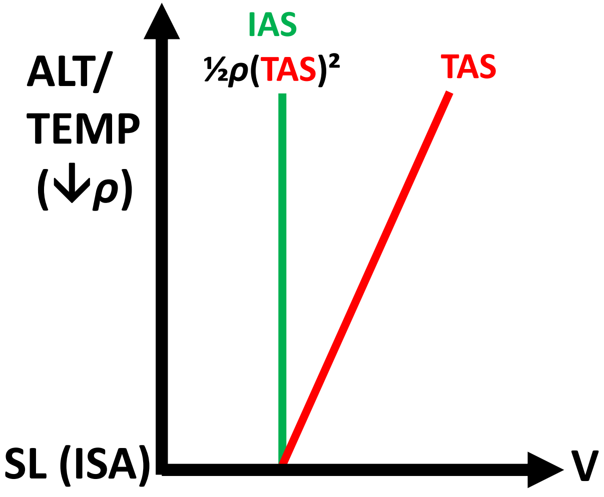
When the dynamic pressure Q (air kinetic energy) pushed on the diaphragm, it will be converted into mechanical energy, resulting in an indication on the airspeed indicated scale. So IAS is simply the dynamic pressure expressed with the wrong unit.

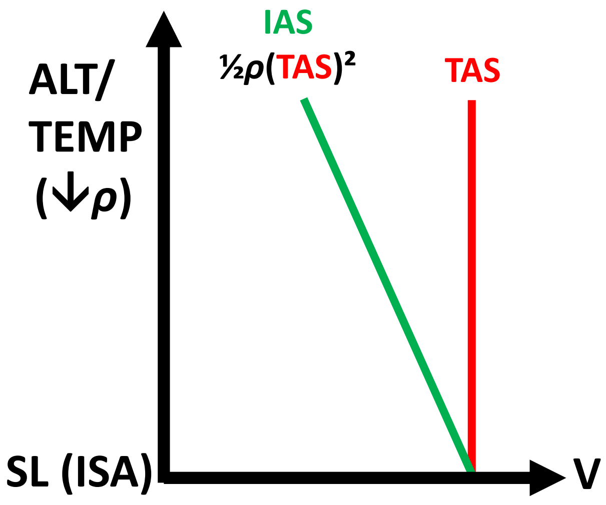
So we can write **IAS=Q**



The airspeed indicator is calibrated at Sea Level in ISA (where ρ=1.225 kg/m^3) to indicate the real/true airspeed (TAS) of the aircraft. So **at Sea Level in ISA, IAS=TAS**.

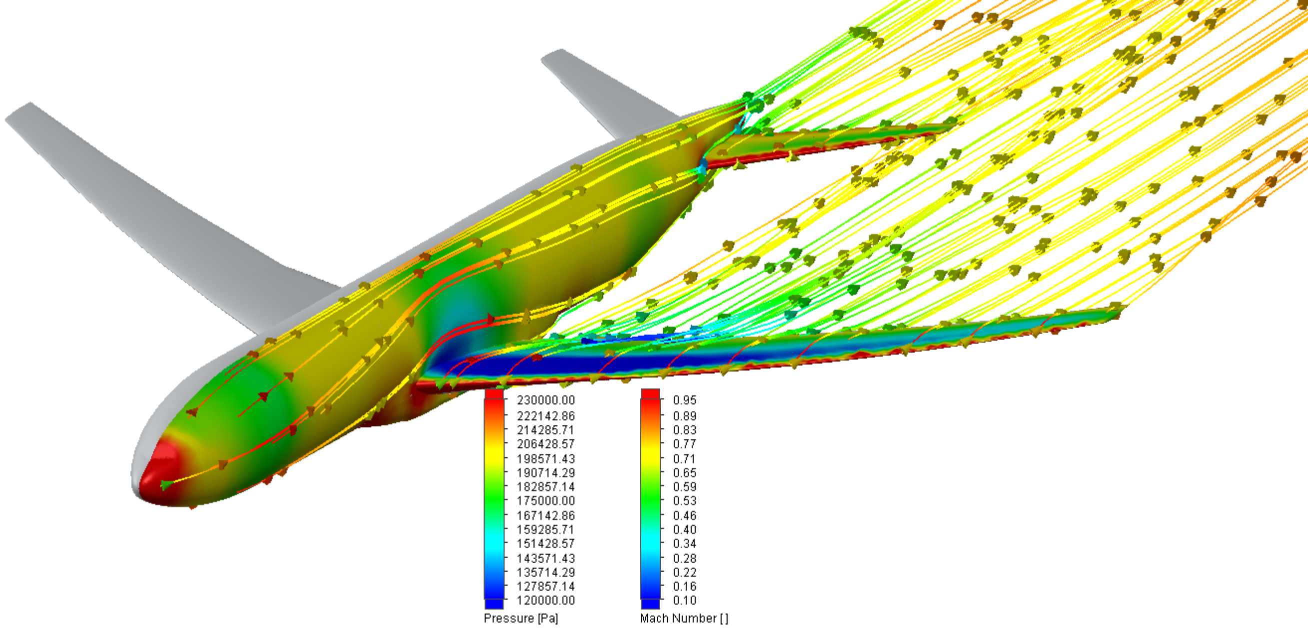
However, at higher altitude or temperature where the density decreases, for a constant IAS, TAS is higher (look at the equation.)





Speed Measurement

Calibrated Airspeed (CAS)



The airflow around the aircraft isn't the same due to the shape of the aircraft and the material (fluid mechanics).
This means that the dynamic pressure pushing the diaphragm isn't the same as the dynamic pressure of the air mas moving around the aircraft. The imperfection and the position of the pitot tube cause the Indicated Airspeed to be wrong. When correction for the instrument and position error, we obtain the real value of the Indicated Airspeed that should be displayed by the airspeed indicator, we call this value the Calibrated Airspeed (CAS).

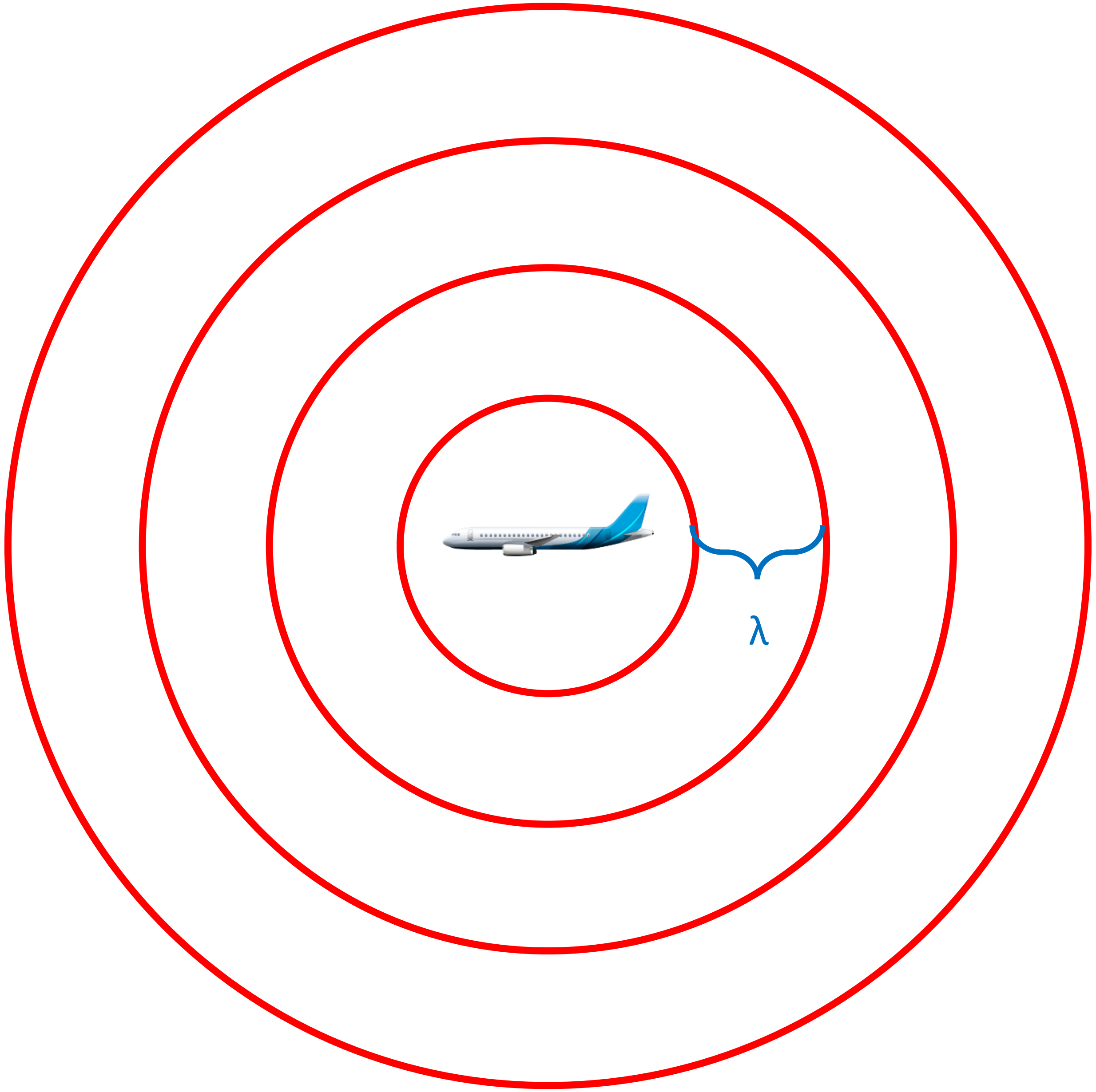
In this lesson, we will assume that there is no instrument and position error, and that the Calibrated Airspeed is equal to the Indicated Airspeed (CAS=IAS)

Speed Measurement

Compressibility effect

When an object is in motion, it disturbs the air molecules around causing a mechanical wave, called pressure wave, and it is moving at the speed of sound.

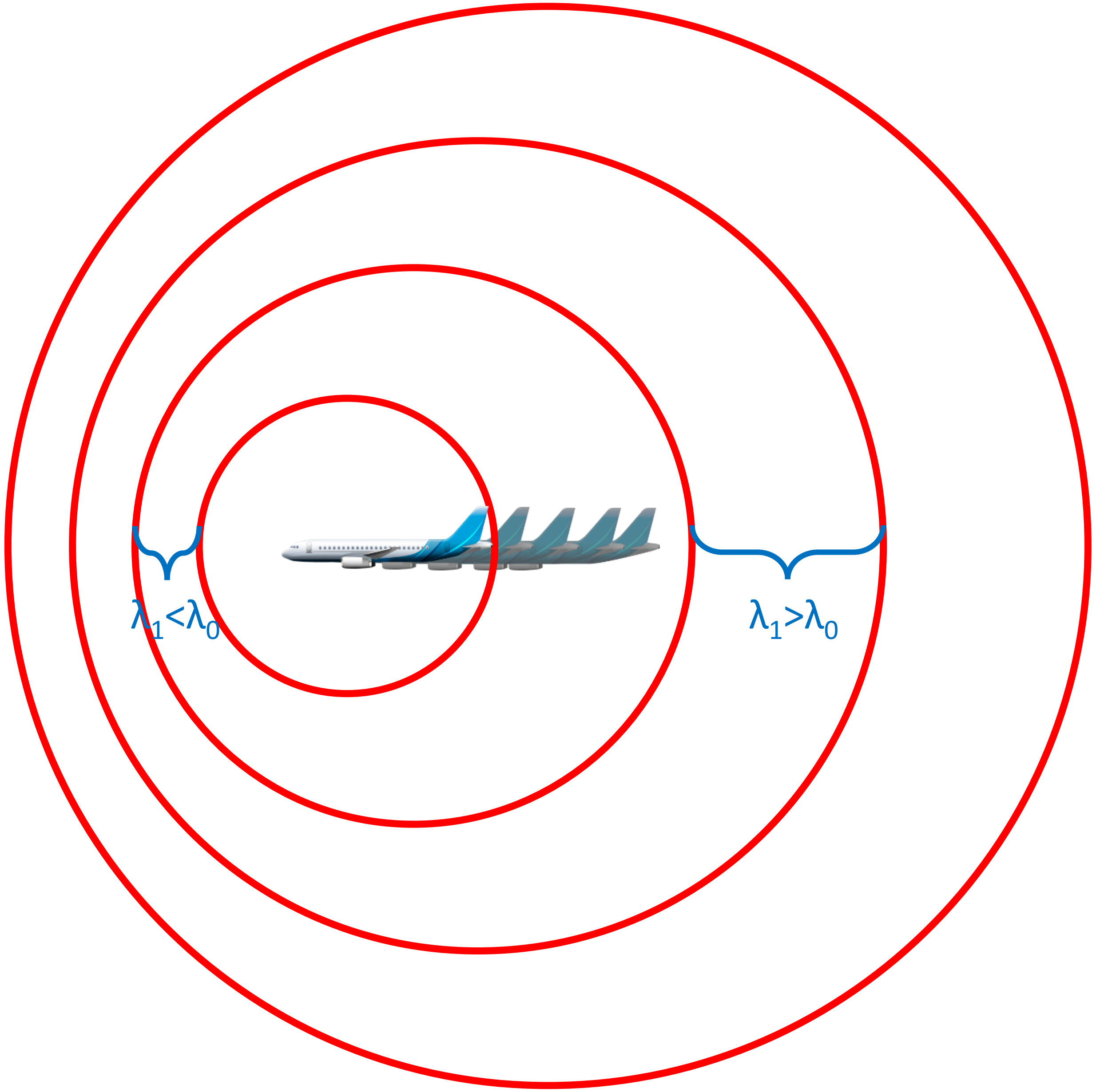
Here are pressure waves originating from a static object (aircraft). We can see that they are equally spaces with the space wave length λ.



Speed Measurement

Compressibility effect

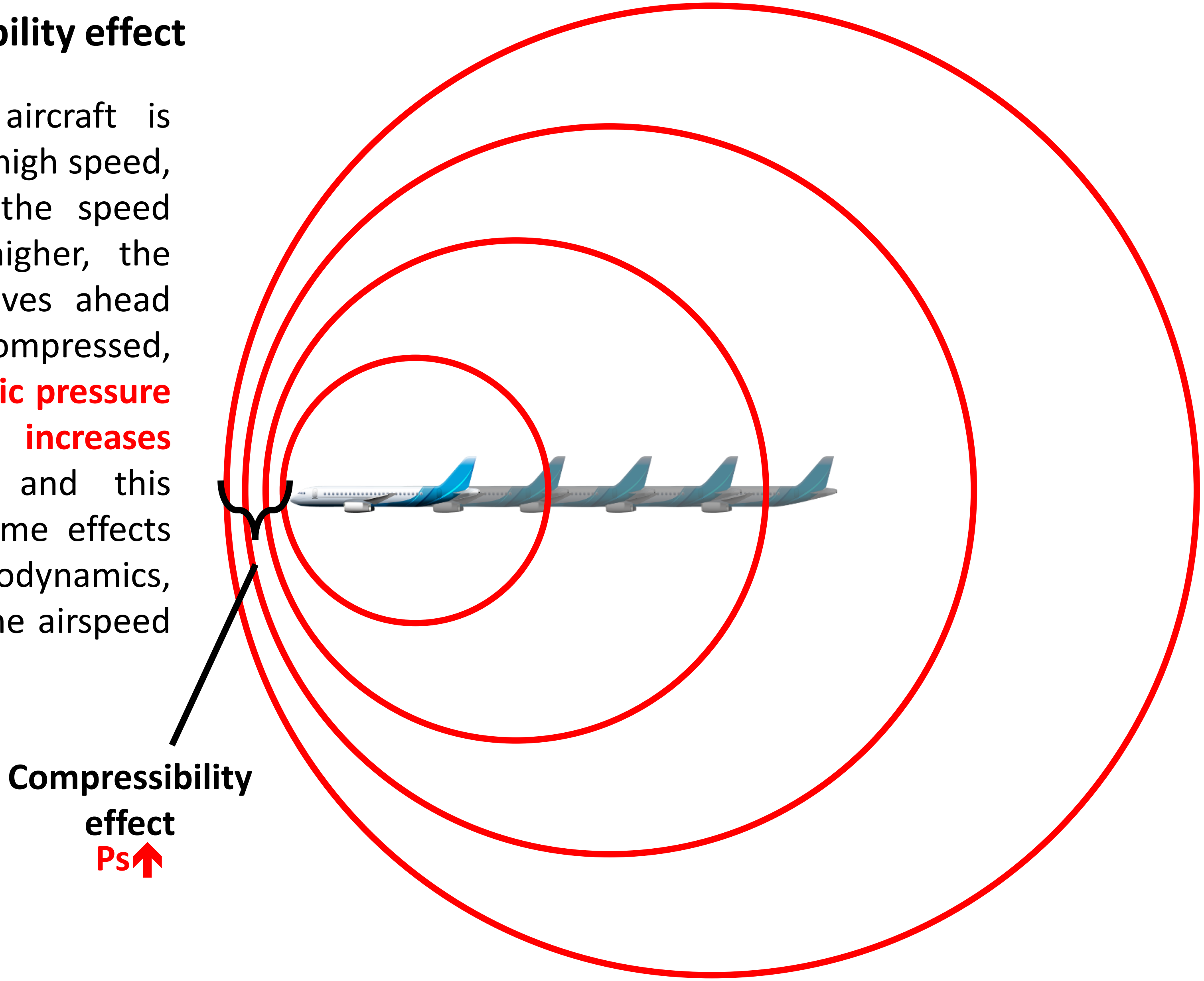
When the aircraft is moving, it will move toward its pressure wave compressing the pressure wave ahead and expanding the pressure wave behind This effect is known as the Doppler Effect.



Speed Measurement

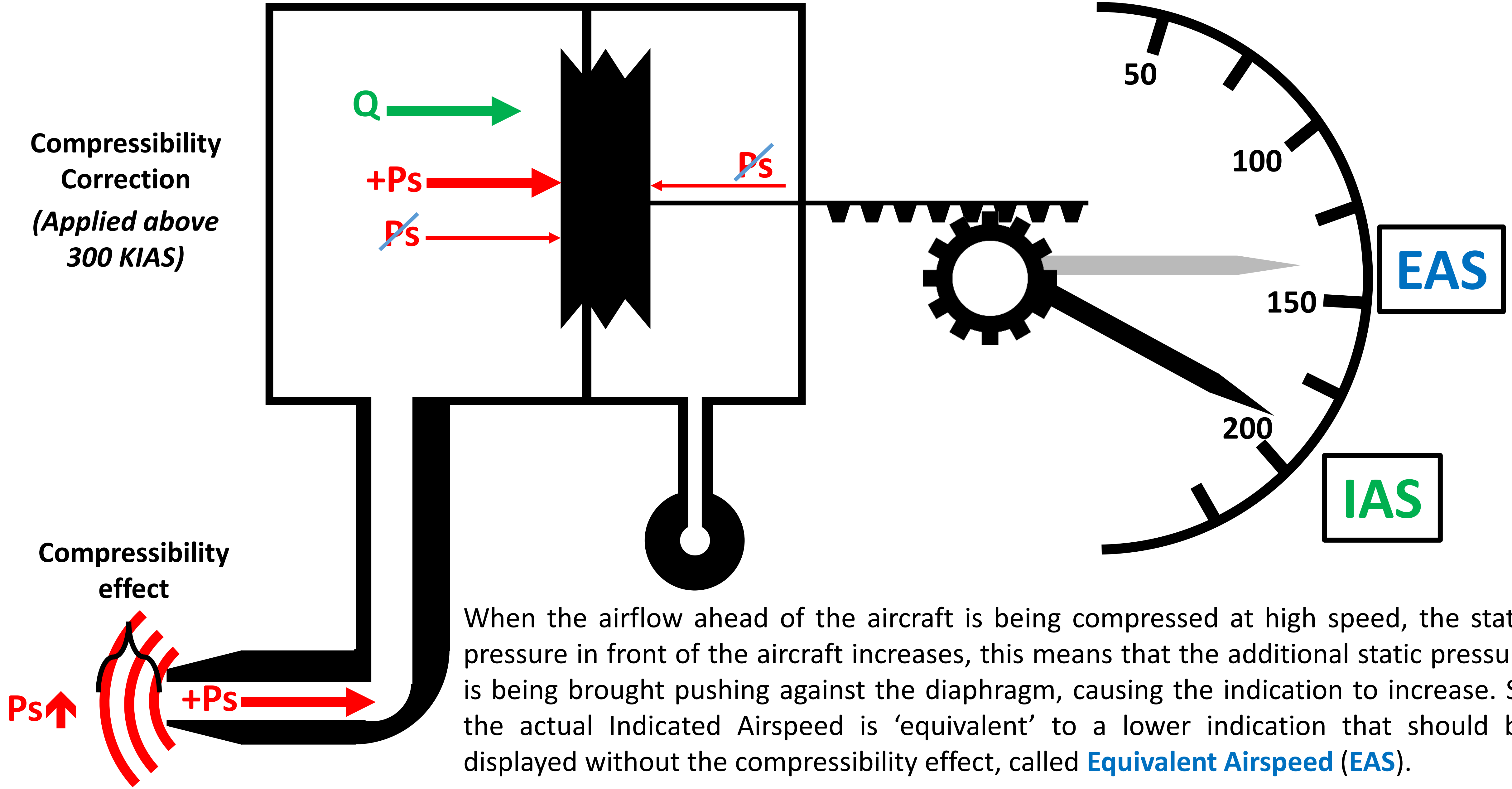
Compressibility effect

When the aircraft is moving at a high speed, at 40% of the speed sound or higher, the pressure waves ahead will be so compressed, that the **static pressure** (**Ps**) **ahead increases** significantly and this will have some effects on the aerodynamics, as well on the airspeed indicator.



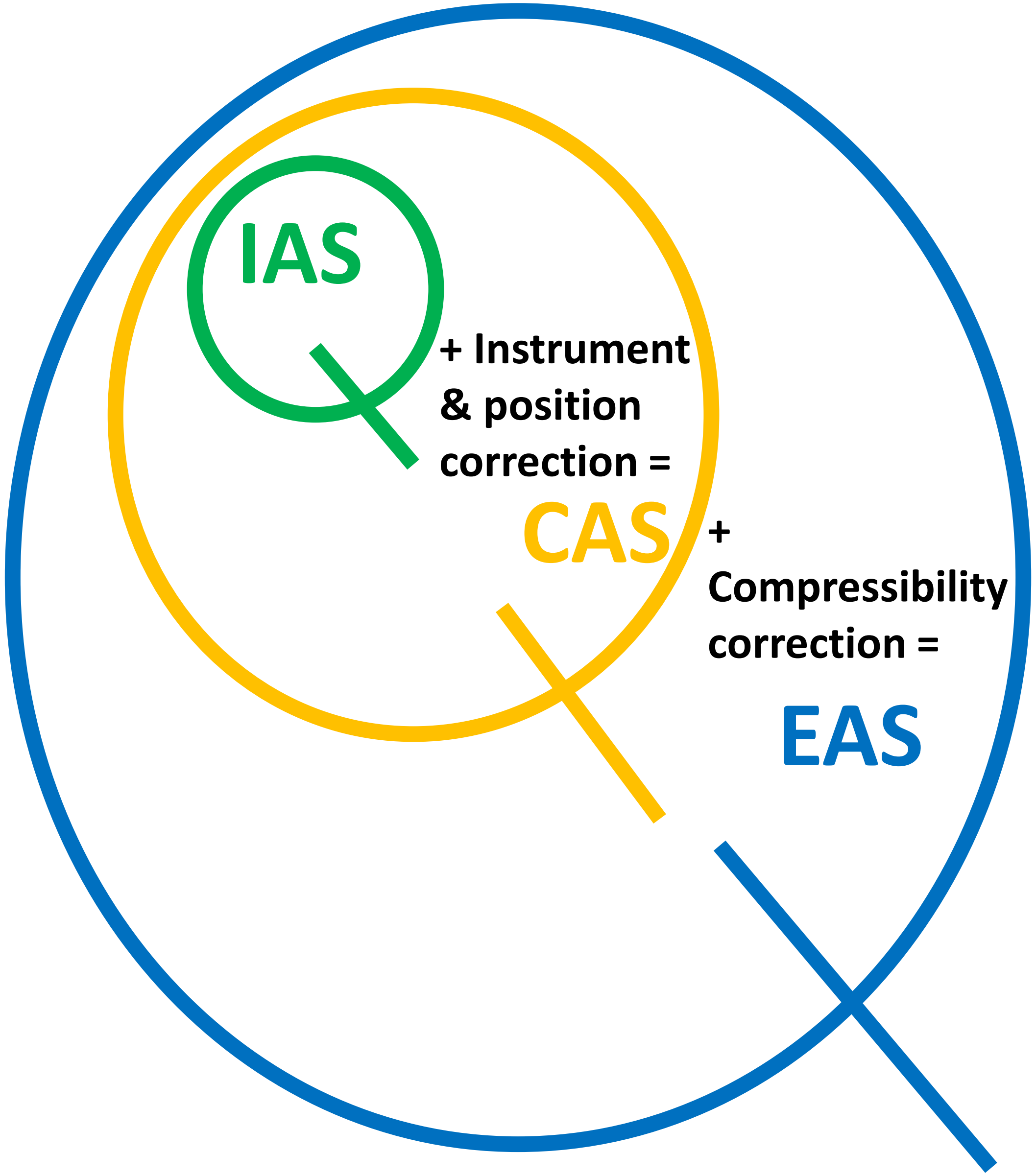
Speed Measurement

Equivalent Airspeed (EAS)



When the airflow ahead of the aircraft is being compressed at high speed, the static pressure in front of the aircraft increases, this means that the additional static pressure is being brought pushing against the diaphragm, causing the indication to increase. So the actual Indicated Airspeed is 'equivalent' to a lower indication that should be displayed without the compressibility effect, called **Equivalent Airspeed** (**EAS**).

Speed Measurement



$$= \tfrac{1}{2}\,\rho\,(\mathrm{TAS})^2$$

$$\mathrm{TAS} = \mathrm{IAS} \times \sqrt{1.031^{\,\mathrm{ALT}/1000} \times 1.0035^{\,\mathrm{ISA\ dev}}}$$

Speed Measurement

Mach Number

When the speed reaches 40% of the speed of sound, the compressibility effect cannot be ignored since a significant change of the fluids' parameters appear. Indeed this affect the flight characteristic, so in flight the airspeed relative to the speed of sound shall be monitored. Therefore we monitor the **Mach Number**, which is **the ratio (or percentage) between the aircraft's True Airspeed and the Local Speed Sound (LSS)**.

The Mach number is named after Austrian physicist and philosopher Ernst Mach (1838–1916), and is a designation proposed by aeronautical engineer Jakob Ackeret (1898–1981) in 1929.

Ernst Mach (1838–1916)

Jakob Ackeret (1898–1981)

$$M = \frac{TAS}{LSS}$$

We need to mention the **Local Speed Sound (LSS)** and not the Speed of Sound because this latter isn't constant and depends on the environment. In the air, the Local Speed of Sound depends on the temperature only.

$$LSS\ (kt) = 38.95 \text{ x} \sqrt{T°C + 273}$$

We can therefore re-write the equation as:

$$M = \frac{TAS}{38.95 \text{ x} \sqrt{T°C + 273}}$$

We call a speed:

- **Subsonic** when **M<1**
- **Sonic** when **M=1**
- **Supersonic** when **M>1**
- **Transonic** when **M_{CRIT}≤M≤1.2**
- **Hypersonic** when **M≥5**
- **High-hypsersonic** when **M≥10**

Speed Measurement

Mach Number

Climb results in
Descent results in

constant: IAS

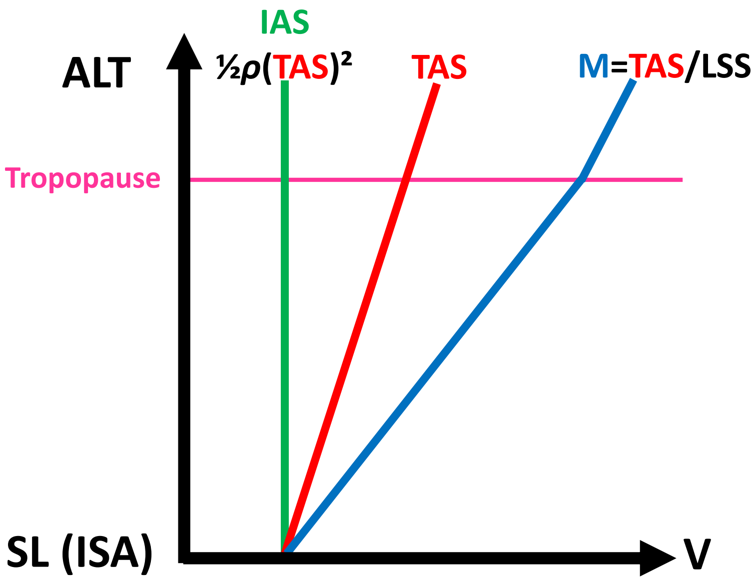
$$M = \frac{IAS \times \sqrt{1.031^{ALT/1000}}}{38.95 \times \sqrt{T_{ISA}°C + 273}}$$

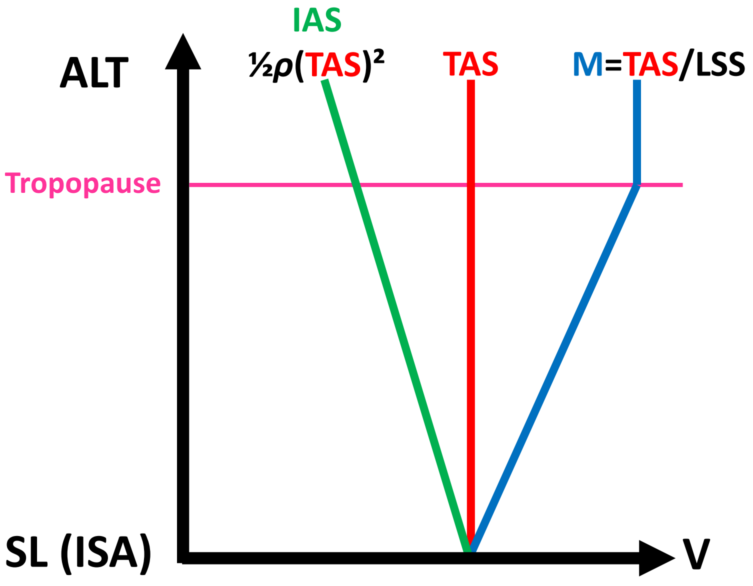
constant: TAS

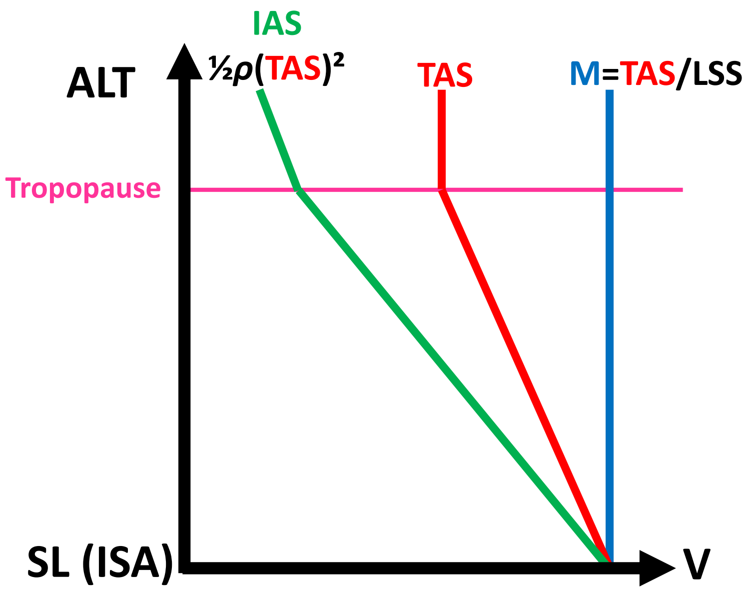
$$M = \frac{TAS}{38.95 \times \sqrt{T°C + 273}}$$

constant: M

$$M = \frac{TAS}{38.95 \times \sqrt{T°C + 273}}$$







In climb at a constant IAS, the Mach number increase, therefore at the 'cross-over altitude' or 'change over-altitude', we need to monitor the M indicator to not exceed M_{MO}. However in descent at a constant Mach Number, the IAS increases, therefore at the 'cross-over altitude' or change 'over-altitude', we need to monitor the Airspeed indicator to not exceed V_{MO}.

Speed Measurement Conversion Summary

Relationship between Indicated Airspeed (IAS) and True Airspeed (TAS) assuming no position and instrument error

$$TAS = IAS \times \sqrt{1.031^{ALT/1000} \times 1.0035^{ISA\ dev}}$$

Mach Number (M) is the ratio (or percentage) between the aircraft's True Airspeed and the Local Speed Sound (LSS)

$$M = \frac{TAS}{LSS}$$

Local Speed of Sound

$$\text{LSS (kt)} = 38.95 \times \sqrt{T°C + 273}$$

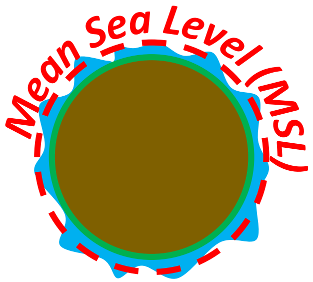
$$M = \frac{TAS}{38.95 \times \sqrt{T°C + 273}}$$

Altitude

Indicated Altitude (IA)

The Indicated Altitude is the altitude displayed according to QNH setting.

The altimeter displays 30’ per 1 hPa of differential pressure between the outside pressure where the aircraft is, and the pressure set in the Kollsman window.



[30’/ 1 hPA]

Kollsman window

Knob for Pressure Setting

QNH 1020 hPa
- 920 hPa
Δ100 hpa x30’/hPa = 3000’ AMSL

Set QNH
➢ Altitude

Local Pressure 920 hPa

Set QFE
➢ Height

QFE 990 hPa
- 920 hPa
2100’ AGL = 30’/hPa x Δ70 hpa

Altitude = Height + elevation

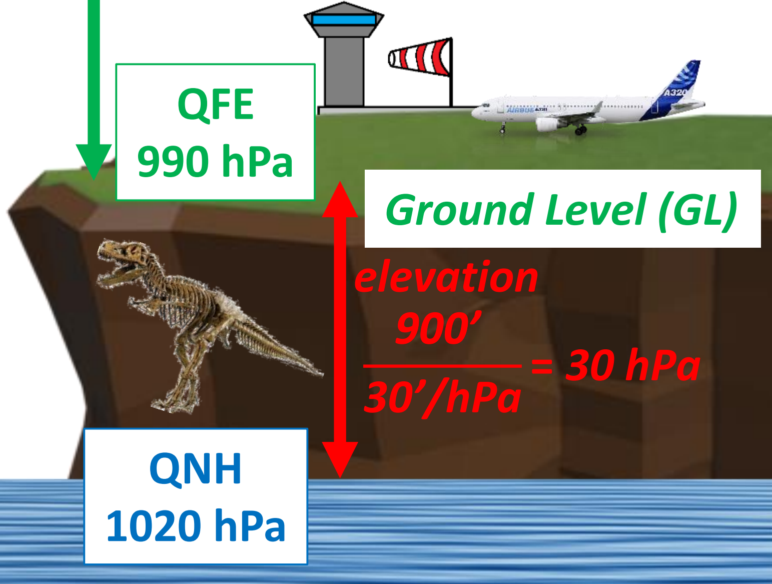
On the ground:

- ➢ Set QNH, shows elevation
- ➢ Set elevation, shows QNH
- ➢ Set QFE, shows 0’
- ➢ Set 0’, shows QFE

1010 hPa ← -10hPa	1020 hPa → +10hPa	1030 hPa
- 920 hPa	- 920 hPa	- 920 hPa
Δ90 hpa x30’/hPa	Δ100 hpa x30’/hPa	Δ110 hpa x30’/hPa
= 2700’	= 3000’	= 3300’

-10hPa x30’/hPa=(-300’) ← ; → +10hPa x30’/hPa=(+300’)

- ➢ **Increase** pressure setting, **increases** the indication by **30’/hPa**
- ➢ **Decrease** pressure setting, **decreases** the indication by **30’/hPa**

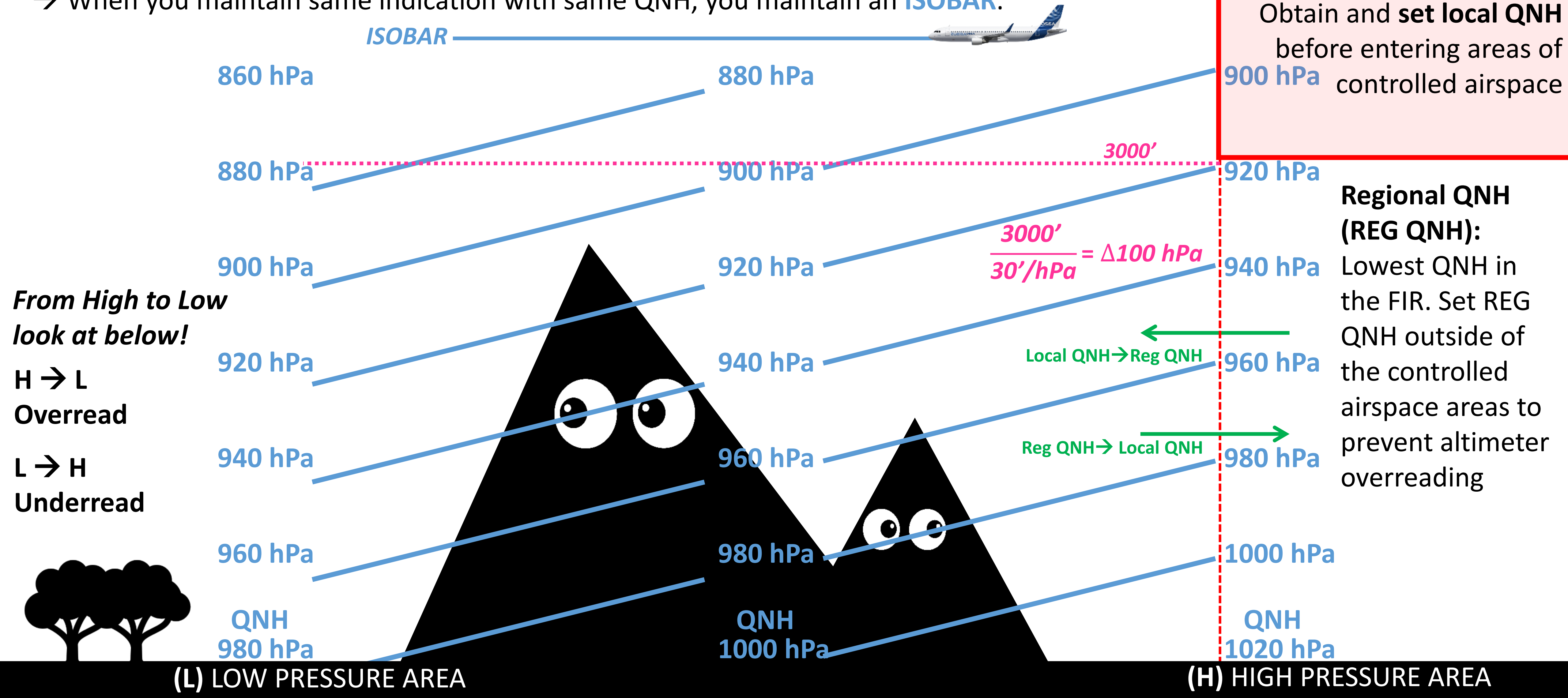


Mean Sea Level (MSL)

Altitude

When maintaining the same indicated altitude, so the altimeter senses the same differential between the pressure setting (QNH) and the outside pressure. With the same QNH setting and same indicated altitude the aircraft follows a line of same pressure, called **ISOBAR**.

→ When you maintain same indication with same QNH, you maintain an **ISOBAR**.



Altitude

Pressure Altitude (PA)

The Pressure altitude is the altitude displayed according to Standard setting.

The Standard setting (STD) is the standard QNH=1013.25 hPa, or 1013.25 mb, or 29.92 inHg. Also called QNE

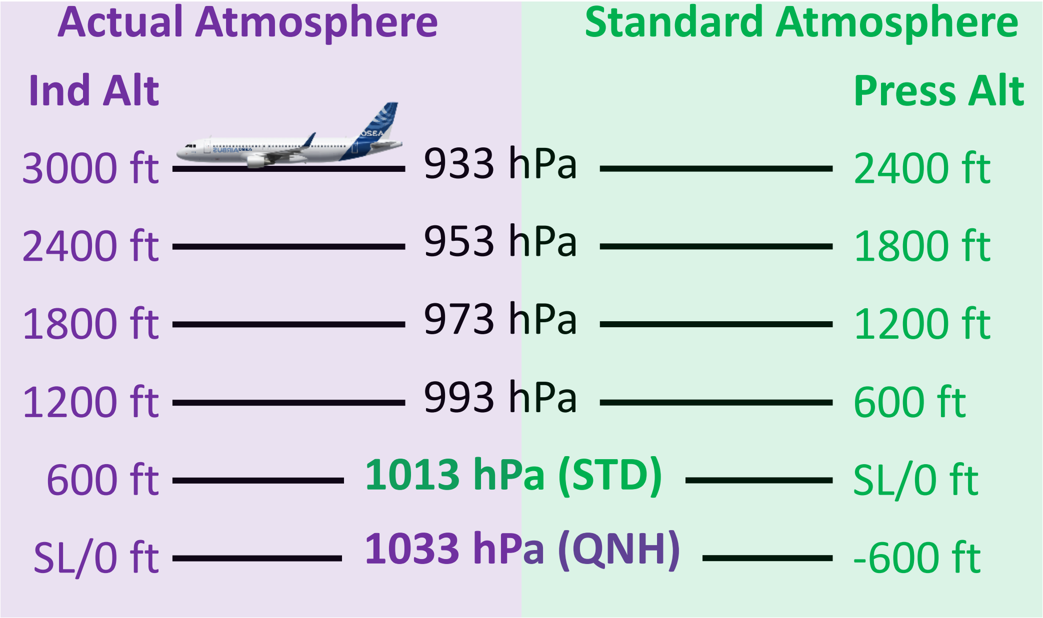
The Pressure Altitude is the theoretical altitude given than, the actual pressure is equivalent to an altitude if the atmosphere was standard.

For demonstration and quick calculation purpose, we will round up the value of the STD to 1013 hPa.

Eg. An aircraft maintaining **3000 ft Indicated Altitude** on **QNH 1033 hPa**,

$$\frac{3000'}{30'/\text{hPa}} = \Delta 100 \text{ hPa}$$

1033 hPa - Δ100 hPa = 933 hPa



To read **3000 ft Indicated Altitude**, the aircraft is maintaining an **ISOBAR** of 933 hPa. However if we look at the pressure scale and we compare the **actual atmosphere** with the **Standard Atmosphere**, we see that actually the pressure 1033 hPa is located 600 ft below Sea Level (SL). So in theory, the aircraft is flying at **2400 ft** in **Standard Atmosphere**. This is called **Pressure Altitude** because the **pressure 933 hPa** corresponds to **2400 ft** in **Standard Atmosphere**.

The Pressure Altitude is used for performance calculation, and used as a Standard Setting for the altimeter that will be explain later.

The Pressure Altitude is also known as **Flight Level (FL)**. To read a Flight Level, omit the last two digits from the Pressure Altitude.

Eg. PA 24000 ft is **FL240** or PA 3000 ft is **FL30** or **FL100** is PA 10000 ft

Altitude

Pressure Altitude (PA)

Pressure Altitude = Indicated Altitude + [30 x (1013 – actual QNH)]
Indicated Altitude = Pressure Altitude + [30 x (actual QNH – 1013)]

An easier way to calculate the Pressure Altitude from the Indicated Altitude, is to think:

If this is the Indicated Altitude displayed by my altimeter when the actual QNH is set, what will my altimeter display if increase or decrease the setting to 1013 hPa?

Remember:

- Increase pressure setting on the altimeter, the indication increases by **30'/hPa**
- Decrease pressure setting on the altimeter, the indication decreases by **30'/hPa**

To obtain the Indicated Altitude from the Pressure Altitude, think the other way round:

If this is the Pressure Altitude displayed by my altimeter when the 1013 hPa is set, what will my altimeter display if increase or decrease the setting to the actual QNH?

Eg. While maintaining FL200, what is the Indicated Altitude if the QNH is 1023 hPa given by the local station?

Indicated Altitude = Pressure Altitude + [30 x (actual QNH – 1013)]

Indicated Altitude = 20,000 + [30 x (1023 – 1013)] = 20,000 + [30 x (+10)] = 20,000 + (+300)

Indicated Altitude = 20,300 ft

→ *If you read PA 20,000 ft with 1013 hPa set, what will you read if you set QNH 1023 hPa by increasing the setting by 10 hPa?*

If you increase the setting by 10 hPa: (+10hPa) x 30'/hPa = +300 ft → the altimeter display will increase by 300 ft.

→ So the Indicated Altitude is 20,300 ft.

Altitude

Pressure Altitude (PA)

Pressure Altitude = Indicated Altitude + [30 x (1013 – actual QNH)]
Indicated Altitude = Pressure Altitude + [30 x (actual QNH – 1013)]

Eg. While maintaining FL150, what is the Indicated Altitude if the QNH is 993 hPa given by the local station?

Indicated Altitude = Pressure Altitude + [30 x (actual QNH – 1013)]

Indicated Altitude = 15,000 + [30 x (993 – 1013)] = 15,000 + [30 x (-20)] = 15,000 + (-600)

Indicated Altitude = 14,400 ft

→ *If you read PA 15,000 ft with 1013 hPa set, what will you read if you set QNH 993 hPa by decreasing the setting by 20 hPa?*

If you decrease the setting by 20 hPa: (-20hPa) x 30'/hPa = -600 ft → the altimeter display will decrease by 600 ft.

→ **So the Indicated Altitude is 14,400 ft.**

Eg. You depart from an aerodrome located at 1000 ft AMSL and the QNH is 988 hPa. What is the Pressure Altitude of the aerodrome?

Pressure Altitude = Indicated Altitude + [30 x (1013 – actual QNH)]

Pressure Altitude = 1,000 + [30 x (1013 – 988)] = 1,000 + [30 x (+25)] = 1,000 + (+750)

Pressure Altitude = 1,750 ft

→ *On the ground with QNH 988 hPa set, you read the elevation which is 1,000 ft, what will you read if you set STD 1013 hPa by decreasing the setting by 25 hPa?*

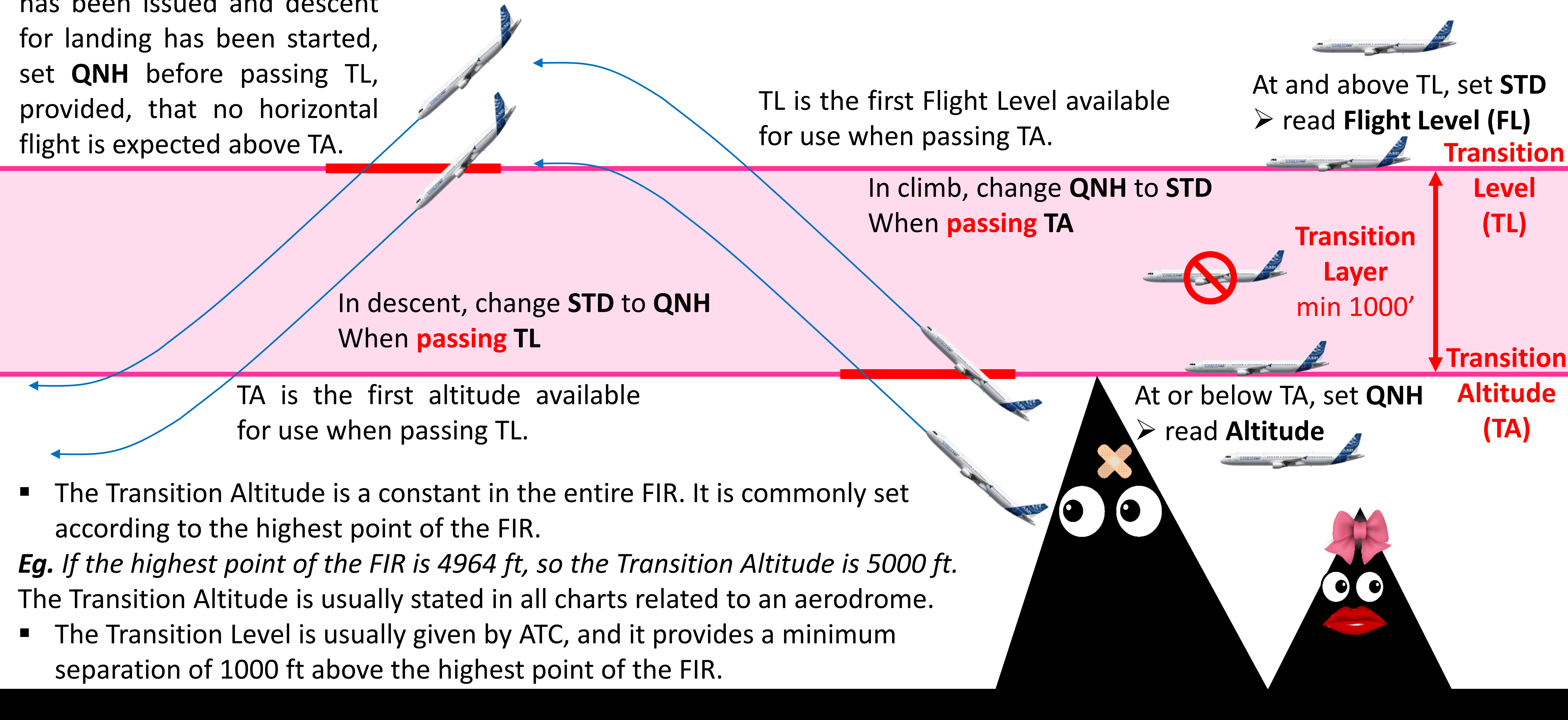
If you increase the setting by 25 hPa: (+25hPa) x 30'/hPa = +750 ft → the altimeter display will increase by 750 ft.

→ **So the Pressure Altitude of the aerodrome is 1,750 ft.**

Altitude

Altimeter setting procedures

When clearance for approach has been issued and descent for landing has been started, set **QNH** before passing TL, provided, that no horizontal flight is expected above TA.



- The Transition Altitude is a constant in the entire FIR. It is commonly set according to the highest point of the FIR.

Eg. *If the highest point of the FIR is 4964 ft, so the Transition Altitude is 5000 ft.*

The Transition Altitude is usually stated in all charts related to an aerodrome.

- The Transition Level is usually given by ATC, and it provides a minimum separation of 1000 ft above the highest point of the FIR.

Transition altitude
Transition altitude is the altitude at or below which the vertical position of an aircraft is controlled by reference to altitudes

Transition level
Transition level is the lowest flight level available for use, located at least 1000 ft (300 m) above the transition altitude

Transition layer
Transition layer is the airspace between the transition level and the transition altitude is called the transition layer. Level flight is not permitted within the transition layer except especially approved activities.
Minimum depth of transition layer is set to 1000 ft in accordance with ICAO Doc. 7030/5

References to the vertical position
The vertical position of aircraft shall be expressed in terms of:
a) flight levels for flight at or above the transition level;
b) altitudes for flight at or below transition altitude;
c) heights above the ground for en−route flight up to 1000 ft (300 m) above the ground;
While passing through the transition layer, vertical position shall be expressed in term of:
i) flight levels when climbing; and
ii) altitude when descending
When clearance for approach has been issued and descent for landing has been started, vertical position of aircraft can be expressed in terms of altitude (QNH), provided, that no horizontal flight is expected above transition altitude.

The change in reference from altitude to flight levels and vice versa
The change in reference from altitude to flight levels and vice versa is made:
1) at the transition altitude when climbing; and
2) at the transition level when descending.

Altitude

Density Altitude (PA)

The Density altitude is the Pressure Altitude corrected for ‘non-standard’ temperature.

The Density Altitude is mainly used for performance calculation. It is to define, for a given Pressure Altitude in ‘non-standard’ atmosphere, what is the equivalent altitude for the actual density for that Pressure Altitude.

Example, if you maintain FL100, normally in Standard Atmosphere, the Outside Air Temperature (OAT) is -5°C.
However, if the actual Outside Air Temperature (OAT) is +5°C, so it is 10° warmer than the Standard Atmosphere. This means that at FL100, the density is less than what it should be, which is actually equivalent to a higher Pressure Altitude where we would obtain the same actual density.

It is important to know the Density Altitude since the density affects the aircraft’s performance such as:

- The aerodynamic forces like the drag, the lift, the surface controls (ailerons, rudder, elevator, etc.)
- Engine performance
- Fuel consumption
- Etc.

Density Altitude = Pressure Altitude + [120 x ISA dev (°C)]

Eg. At FL200, the OAT is -40°C. What is the Density Altitude ?

*At FL200, in ISA the OAT should be -25°C, however here is it -40°C, so here the atmospheric conditions are **ISA-15***

Density Altitude = Pressure Altitude + 120 x ISA dev

Density Altitude = 20,000 + [120 x (-15)] = 20,000 + (-1800)

Density Altitude = 18,200 ft

So while flying at PA 20,000 ft, the aircraft’s performance are the one for PA 18,200. It is like flying at PA 18,200 ft for this density.

Altitude

Density Altitude (DA) in practice

The Density Altitude is mainly used for performance calculation as stated before.

Example, you are planning to fly at 7000 ft AMSL with a Cessna C172S, and you want to know your cruise performance in ISA-20 and the QNH at in the area is 1033 hPa.

→ First determine the aerodrome Pressure Altitude:

Pressure Altitude = Indicated Altitude + [30 x (1013 – actual QNH)]

Pressure Altitude = 7,000 + [30 x (1013 – 1033)] = 7,000 + [30 x (-20)]

Pressure Altitude = 6,400 ft

→ Then calculate the Density Altitude:

Density Altitude = Pressure Altitude + 120 x ISA dev

Density Altitude = 6,400 + [120 x (-20)] = 6,400 + (-2,400)

Density Altitude = 4,000 ft

This means that, the actual atmospheric conditions are the condition for 4000 ft in ISA. So the aircraft will perform as it was at 4000 ft in ISA.

→ **Therefore, refer to the cruise performance data for 4000 ft is standard temperature (ISA).**

CESSNA
MODEL 172S

SECTION 5
PERFORMANCE

CRUISE PERFORMANCE

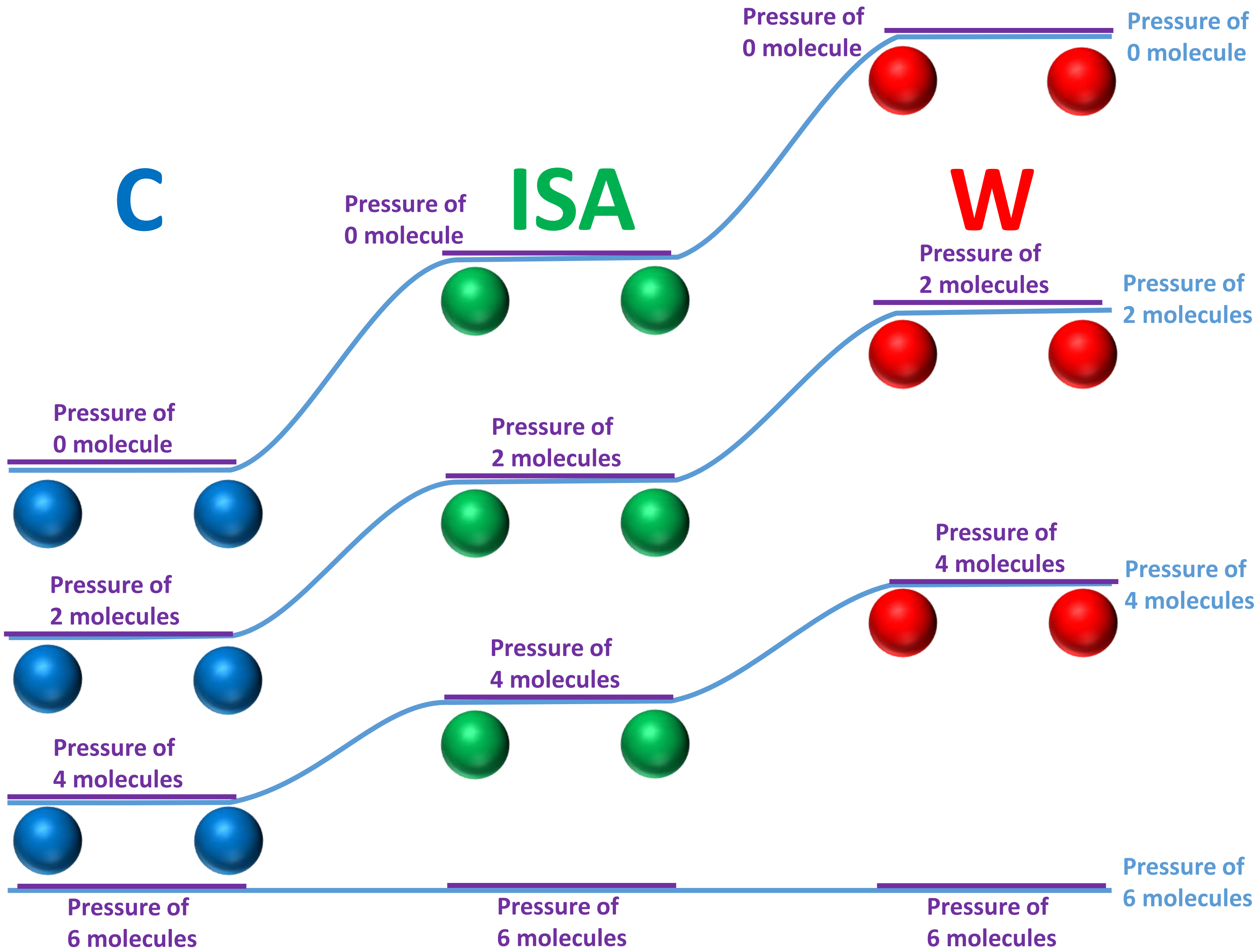
CONDITIONS:
2550 Pounds
Recommended Lean Mixture At All Altitudes (Refer to Section 4, Cruise)

PRESS ALT FT	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% BHP	KTAS	GPH	% BHP	KTAS	GPH	% BHP	KTAS	GPH
2000	2550	83	117	11.1	77	118	10.5	72	117	9.9
	2500	78	115	10.6	73	115	9.9	68	115	9.4
	2400	69	111	9.6	64	110	9.0	60	109	8.5
	2300	61	105	8.6	57	104	8.1	53	102	7.7
	2200	53	99	7.7	50	97	7.3	47	95	6.9
	2100	47	92	6.9	44	90	6.6	42	89	6.3
4000	2600	83	120	11.1	77	120	10.4	72	119	9.8
	2550	79	118	10.6	73	117	9.9	68	117	9.4
	2500	74	115	10.1	69	115	9.5	64	114	8.9
	2400	65	110	9.1	61	109	8.5	57	107	8.1
	2300	58	104	8.2	54	102	7.7	51	101	7.3
	2200	51	98	7.4	48	96	7.0	45	94	6.7
	2100	45	91	6.6	42	89	6.4	40	87	6.1
6000	2650	83	122	11.1	77	122	10.4	72	121	9.8
	2600	78	120	10.6	73	119	9.9	68	118	9.4
	2500	70	115	9.6	65	114	9.0	60	112	8.5
	2400	62	109	8.6	57	108	8.2	54	106	7.7

Altitude

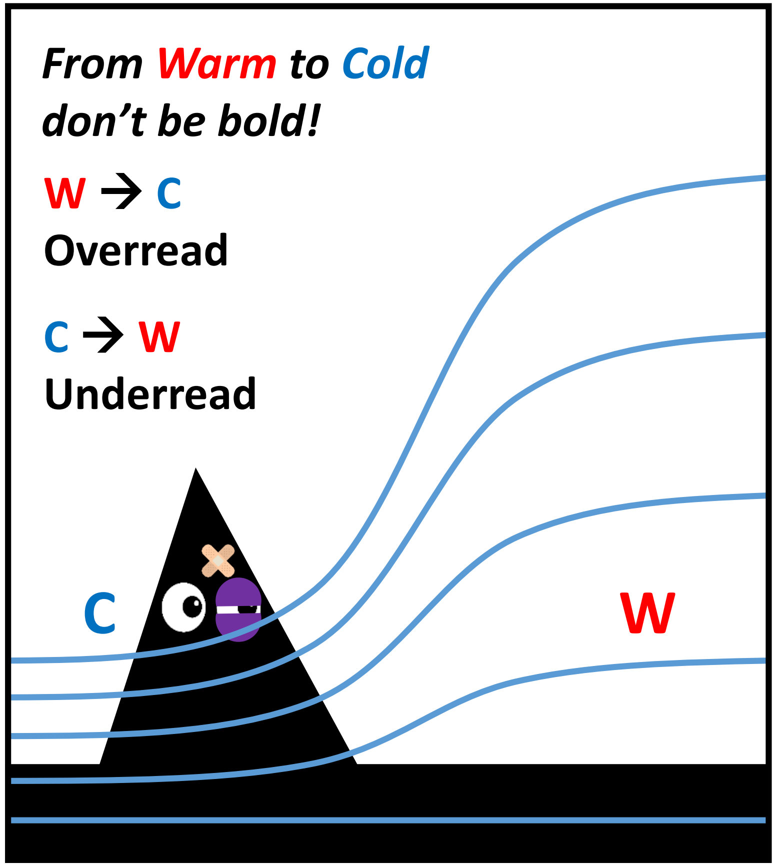
Temperature Effect

In an atmosphere **colder** than **ISA**, the air mass becomes denser and sinks down.
When the atmosphere is **warmer** than **ISA**, the air mass becomes less dense and lifts up.
When drawing the **ISOBARS**, in an atmosphere **colder** than **ISA**, compress closer to the surface.
However, when the atmosphere is **warmer** than **ISA**, the **ISOBARS** expand further from the surface.



When maintaining the same Indicated Altitude, the aircraft is following an **ISOBAR**, so:

- When flying to **colder air**, the aircraft descends
- When flying to **warmer air**, the aircraft climbs



Altitude

True Altitude (TA)

The True Altitude is the Indicated Altitude corrected for the actual temperature.

Space between two ISOBARS different by 37 hPa

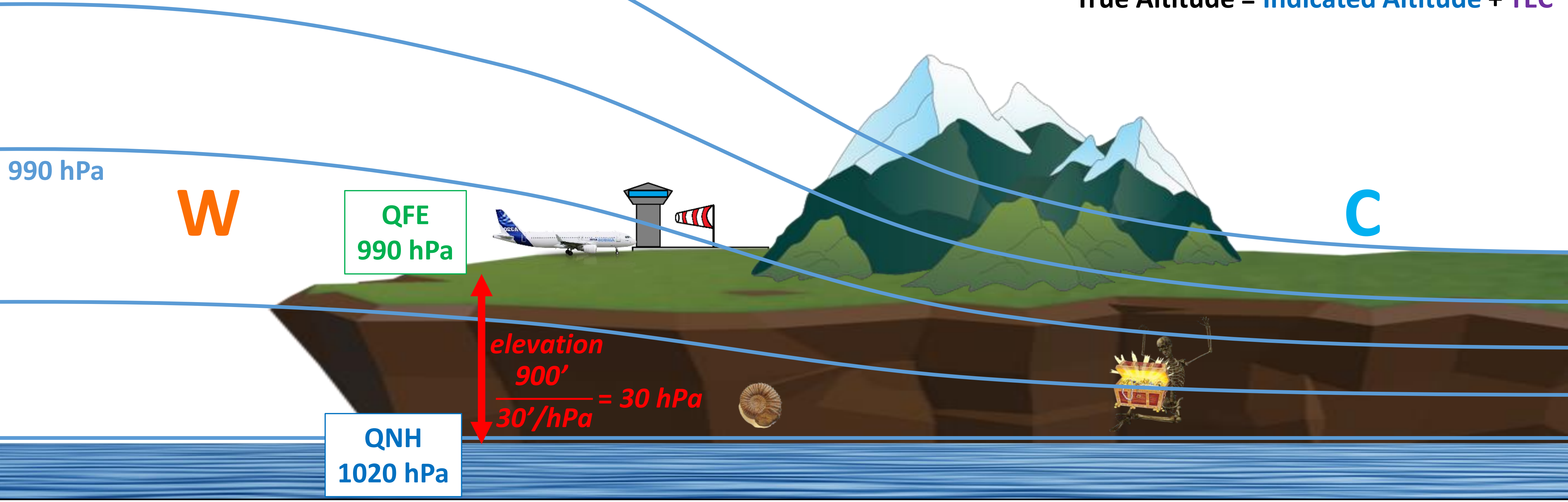
ISA-n, (1000-4n) ft 37hPa | **ISA**, (1000) ft 37hPa | **ISA+n**, (1000+4n) ft 37hPa

height above station = **Indicated Altitude** – **elevation**
(wrong) *(false altitude)* *(correct)*

$$\text{TEC} = 4 \times \frac{\text{height above station (ft)}}{1000} \times \text{ISA dev (°C)}$$

(*or* TEC = 4% of the height above station (ft) per 10°C deviation from ISA)

True Altitude = Indicated Altitude + TEC



When the **QNH** is set on the ground, the altimeter shows the **correct elevation**. However once airborne, the aircraft maintains an altitude by following an **ISOBAR** which is "moving" according to the **temperature deviation from ISA**, so the calculated **height above the station** is **wrong**. So to obtain the **True Altitude**, a **Temperature Error Correction** (**TEC**) is applied to the **height above the station**, which consists of recalculating the space between the **ISOBARS**, because the altimeter shows only 30 ft per 1 hPa.

Altitude Conversion Summary

The Indicated Altitude (IA) is the altitude displayed according to QNH setting

The Pressure altitude (PA) is the altitude displayed according to Standard setting

$$PA = IA + [30 \times (1013 - \text{actual QNH})]$$
$$IA = PA + [30 \times (\text{actual QNH} - 1013)]$$

The Density altitude (DA) is the Pressure Altitude (PA) corrected for ‘non-standard’ temperature

$$DA = PA + [120 \times \text{ISA dev } (°C)]$$

The True Altitude (TA) is the Indicated Altitude (IA) corrected for the actual temperature

$$TA = IA + TEC$$

Temperature Error Correction (TEC) $$TEC = 4 \times \frac{\text{height above station (ft)}}{1000} \times \text{ISA dev } (°C)$$

Height above the station $$\text{height above station} = \text{Indicated Altitude} - \text{elevation}$$