MODULE 08
BASIC AERODYNAMICS

LEVEL-2

Sub-Module 01
PHYSICS OF THE ATMOSPHERE

Source-EASA MODULE 8

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Sub-Module 01
PHYSICS OF THE ATMOSPHERE

BASIC AERODYNAMICS

- Three topics that are directly related to the manufacture, operation, and repair of aircraft are: aerodynamics, aircraft assembly, and rigging.
- By studying aerodynamics, a person becomes familiar with the fundamentals of aircraft flight.

- *Aerodynamics is the study of the dynamics of gases.*
- The interaction between a moving object and the atmosphere is the primary interest in this module.
- The movement of an object and its reaction to the air flow around it can be seen when watching water passing the bow of a ship.
- The major difference between water and air is that air is compressible and water is incompressible.

- The technician must be able to understand the relationships between how an aircraft performs in flight and its reaction to the forces acting on its structural parts.
- Understanding why aircraft are designed with particular types of primary and secondary control systems and why the surfaces must be aerodynamically smooth becomes essential when maintaining today’s complex aircraft.

THE TERM AERODYNAMICS IS DERIVED FROM THE COMBINATION OF TWO GREEK WORDS

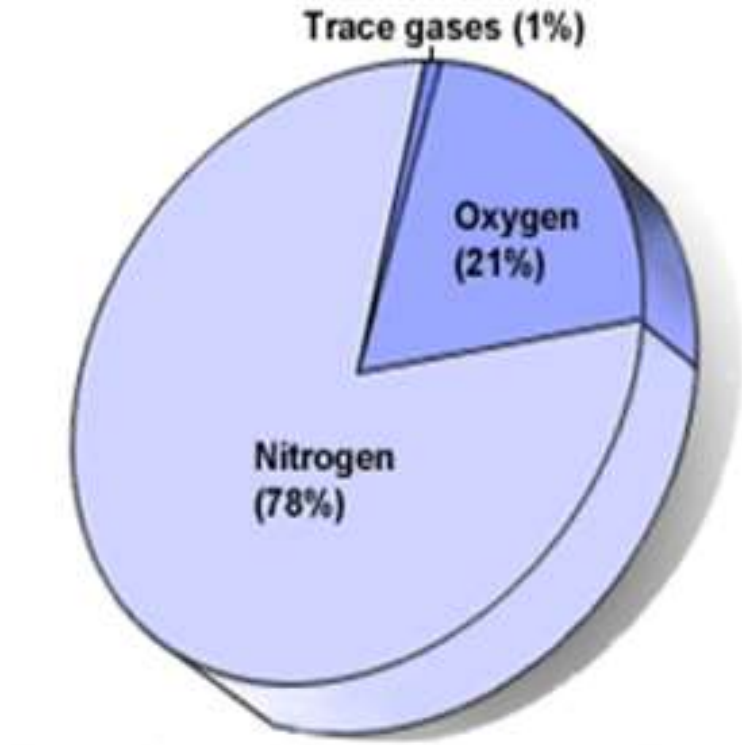
- "**aero**," meaning air, and "**dyne**," meaning force of power.
- Thus, when "aero" joins "dynamics" the result is "***aerodynamics****"—the study of objects in motion through the air and the forces that produce or change such motion.*

PHYSICS OF THE ATMOSPHERE

- The air in the earth's atmosphere is composed mostly of nitrogen and oxygen.
- Air is considered a fluid because it fits the definition of a substance that has the ability to flow or assume the shape of the container in which it is enclosed.
- If the container is heated, pressure increases; if cooled, the pressure decreases.
- The weight of air is heaviest at sea level where it has been compressed by all of the air above. This compression of air is called atmospheric pressure.

ATMOSPHERIC CONTENT

- Composition of air :-
  - 78% - Nitrogen
  - 21% - Oxygen
  - 1% - Other Gases (argon, carbon dioxide, hydrogen, helium, neon, etc.)



OXYGEN

- Human breathing
- Fuel combustion → keep aircraft flying

PHYSICS OF THE ATMOSPHERE

Before examining the fundamental laws of flight, several basic facts must be considered. An aircraft operates in the air. Therefore, those properties of air that affect the control and performance of an aircraft must be understood.

PRESSURE

- ***Atmospheric pressure is usually defined as the force exerted against the earth's surface by the weight of the air above that surface.***
- Weight is force applied to an area that results in pressure. Force (F) equals area (A) times pressure (P), or F = AP.
- Therefore, to find the amount of pressure, divide area into force (P = F/A). A column of air (one square inch) extending from sea level to the top of the **atmosphere weighs approximately 14.7 pounds**; therefore, **atmospheric pressure is stated in pounds per square inch (psi).** Thus, atmospheric pressure at sea level is 14.7 psi.

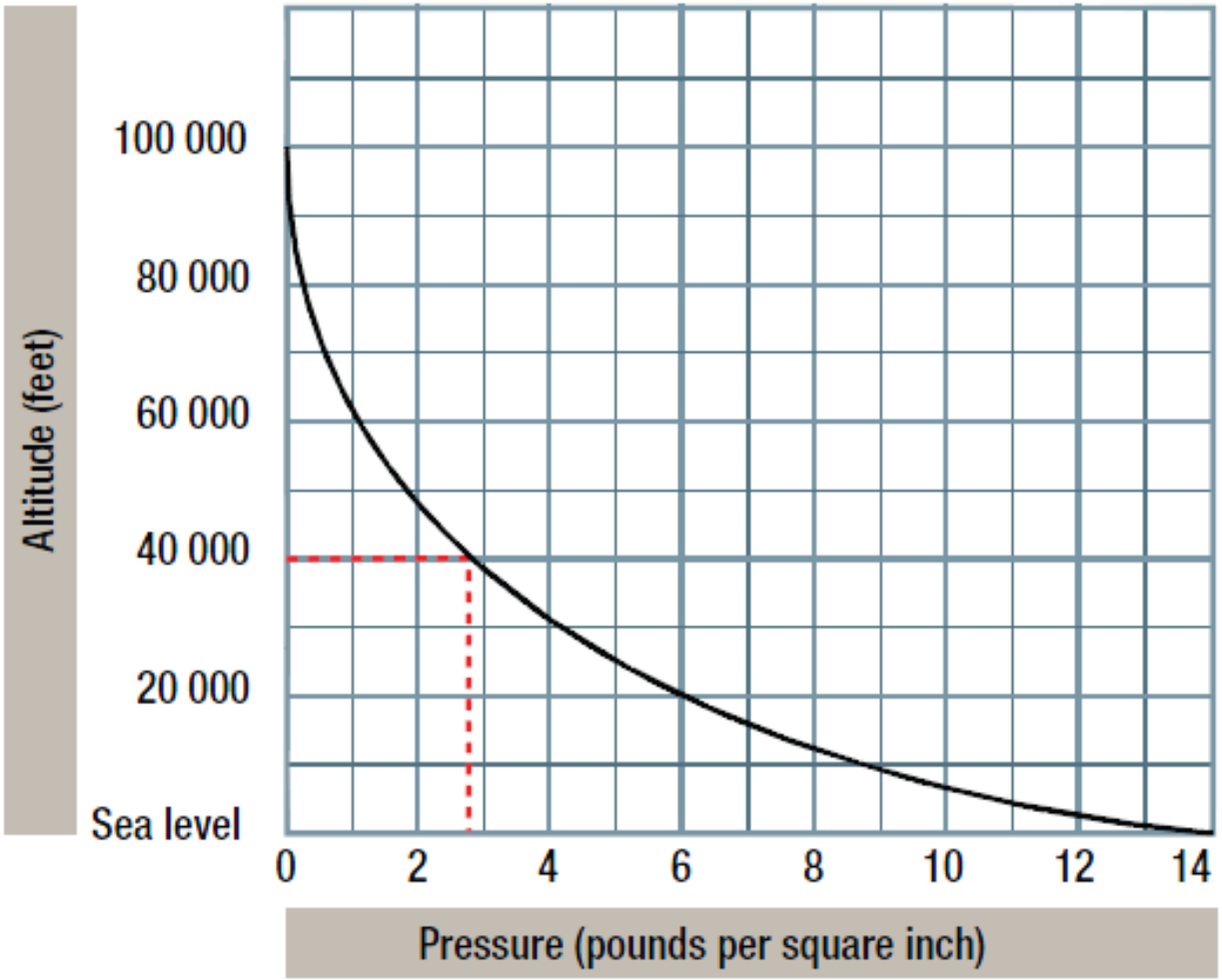
- Atmospheric pressure is measured with an instrument called a barometer, composed of mercury in a tube that records atmospheric pressure in inches of mercury (Hg).

Atmospheric Pressure

- **Standard atmospheric pressure at sea level is also known as 1 atmosphere, or 1 atm. The following measurements of standard atmospheric pressure are all equal to each other.**

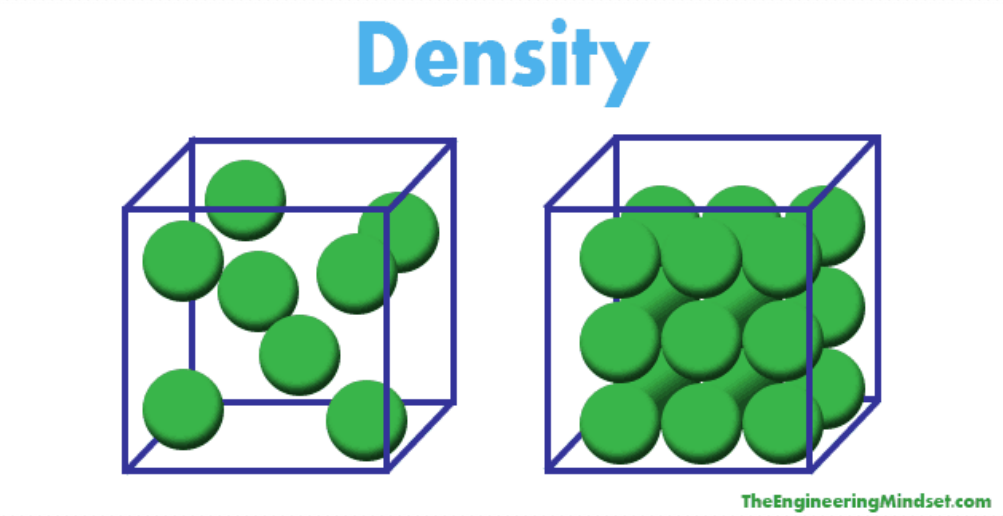
1 atm (atmosphere) = 14.7 psi (pounds per square inch) = 29.92 in Hg (inches of mercury) = 1013.2 hPa (or 101325 newtons per square meters = 1013.2 mb (millibars) = 760 mm Hg (millimeters of mercury)

- Atmospheric pressure decreases with increasing altitude.
- As an aircraft ascends, atmospheric pressure drops, the quantity of oxygen decreases, and temperature drops.
- These changes in altitude affect an aircraft's performance in such areas as lift and engine horsepower.
- The effects of temperature, altitude, and density of air on aircraft performance are covered in the following paragraphs.


Altitude (feet)
100 000
80 000
60 000
40 000
20 000
Sea level
0
2
4
6
8
10
12
14
Pressure (pounds per square inch)

DENSITY

- **Density** is the measurement of how tightly a material is packed together.
- Density is the amount of matter in a specific area.



- Since air is a mixture of gases, it can be compressed.
- If the air in one container is under half as much pressure as an equal amount of air in an identical container, the air under greater pressure is twice as dense as that in the other container.
- For the equal weight of air, that which is under the greater pressure occupies only half the volume of that under half the pressure.

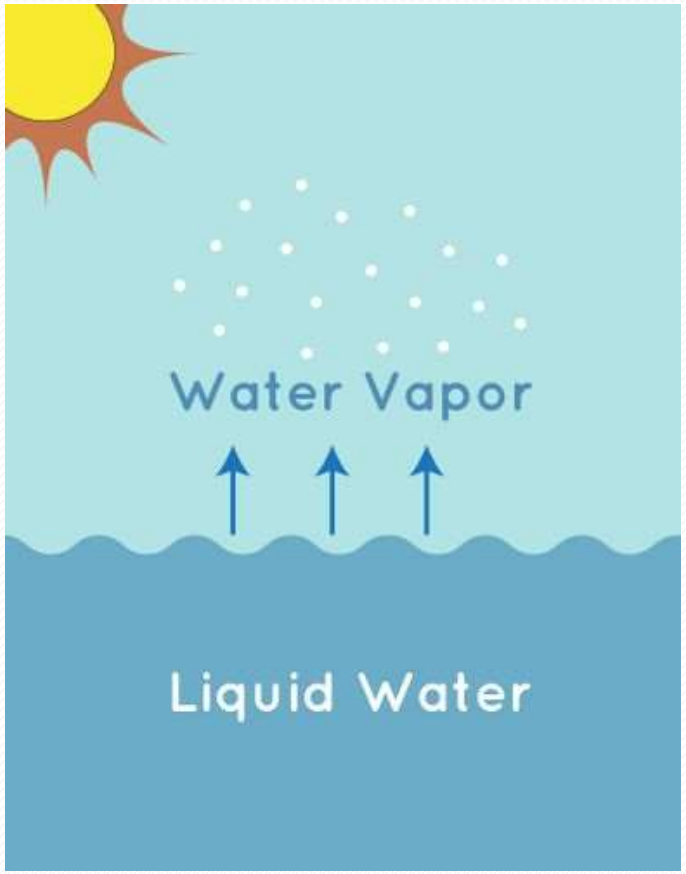
- The density of gases is governed by the following rules:
- 1. Density varies in direct proportion with the pressure.
- 2. Density varies inversely with the temperature.
- air at high altitudes is less dense than air at low altitudes
- and a mass of hot air is less dense than a mass of cool air.
- Changes in density affect the aerodynamic performance of aircraft with the same horsepower. An aircraft can fly faster at a high altitude where the air density is low than at a low altitude where the density is greater. This is because air offers less resistance to the aircraft when it contains a smaller number of air particles per unit of volume.

- **Density at sea level is 1.225** kg/m^3

HUMIDITY

- *Humidity is the amount of water vapor in the air.*
- Humidity is the presence of water vapor in the atmosphere.
- The maximum amount of water vapor that air can hold varies with the temperature. The higher the temperature of the air, the more water vapor it can absorb.

- The actual amount of water vapour in the atmosphere being dependent on the air temperature of the day
- So on hot days air can hold more water vapour.


Water Vapor
Liquid Water

HOW DO WE MEASURE HUMIDITY?

- There are a couple of different means of calculating humidity in absolute and relative terms.

- 1. Absolute humidity
- 2. Relative humidity

Absolute humidity –

- Absolute humidity is the weight of water vapor in a unit volume of air.
- Absolute humidity is simply the total mass of water vapor in a given air volume
- Absolute humidity is the amount of water vapour present in a given mass of air at a particular time and temperature

- **Absolute humidity** is the measure of water vapor (moisture) in the air, regardless of temperature.
- It is expressed as grams of moisture per cubic meter of air (g/m3).

Relative humidity –

- Relative humidity is the ratio, in percent, of the moisture actually in the air to the moisture it would hold if it were saturated at the same temperature and pressure.
- OR
- relative humidity is the ratio of the amount of water vapour present in the atmosphere to the maximum amount of water vapour the air can hold

- **Relative humidity** also measures water vapor but **RELATIVE** to the temperature of the air.
- On damp days, the air density is less than on dry days. For this reason, an aircraft requires a longer runway for takeoff on damp days than it does on dry days.

- **The density of the air varies inversely with the humidity.**

DENSITY increases - **HUMIDITY** Decreases

DENSITY Decreases – **HUMIDITY** Increases

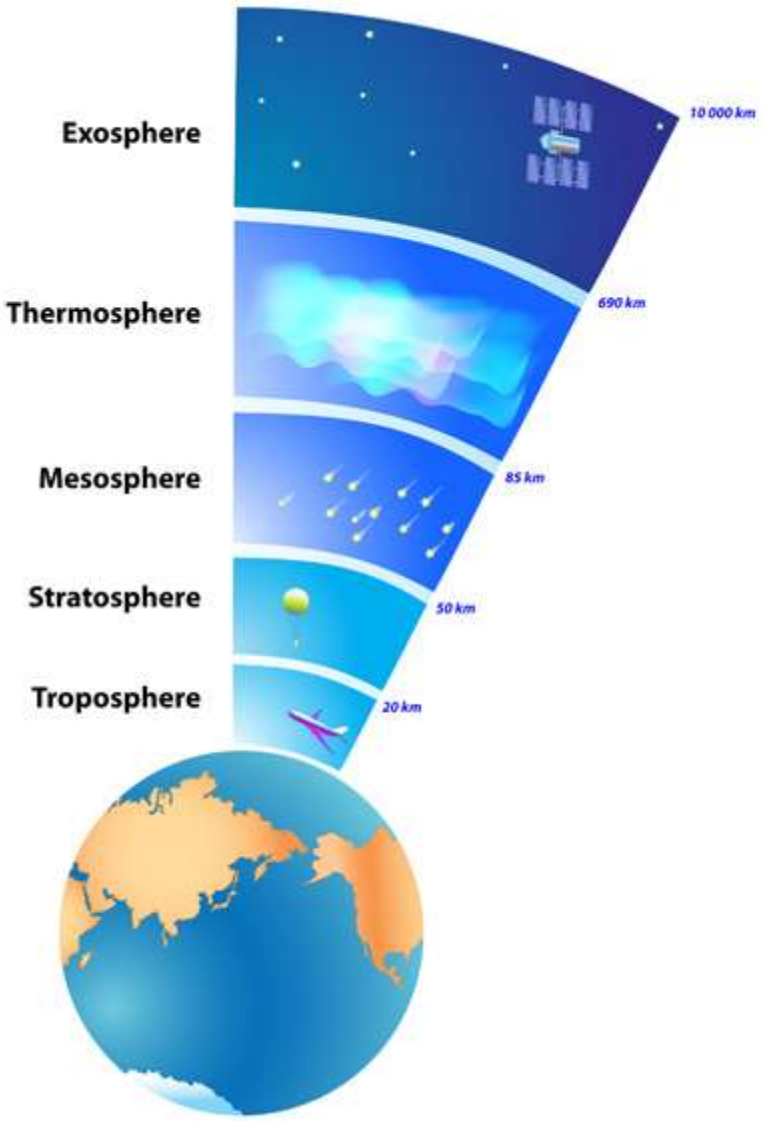
LAYERS OF THE ATMOSPHERE

The different layers of the atmosphere

The atmosphere can be divided into layers based on its temperature.

1) **TROPOSPHERE**
2) **STRATOSPHERE**
3) **MESOSPHERE**
4) **THERMOSPHERE AND IONOSPHERE**
5) **EXOSPHERE**

LAYERS OF THE ATMOSPHERE



TROPOSPHERE

- This is the lowest part of the atmosphere.
- Troposphere: 0 to 12 km (0 to 7 miles)
- It extends from Earth's surface to an average height of about 12 km (7.5 mi; 39,000 ft),
- It contains most of our weather - clouds, rain, snow.
- In this part of the atmosphere the temperature gets colder as the distance above the earth increases, by about 6.5°C per kilometre.
- The troposphere contains about 75% of all of the air in the atmosphere, and almost all of the water vapour (which forms clouds and rain).

- The decrease in temperature with height is a result of the decreasing pressure.
- The top of the troposphere is called the tropopause.
- Most civilian aviation takes place in the troposphere
- in which temperature decreases as altitude increases.
- The rate of change is somewhat constant at about –2 °C or –3.5 °F for every 1 000 feet of increase in altitude.
- The upper boundary of the troposphere is the tropopause.
- It is characterized as a zone of relatively constant temperature of –57 °C or –69 °F.

STRATOSPHERE

- The next layer up is called the **stratosphere**.
- Stratosphere: 12 to 50 km (7 to 31 miles)
- The layer between the troposphere and stratosphere is called tropopause.
- The stratosphere extends from the top of the troposphere to about 50 km (31 miles) above the ground.
- ozone layer is found within the stratosphere.
- The ozone layer **sits in the stratosphere between 15 km and 30 km above the earth**
- Ozone molecules in this layer absorb high-energy ultraviolet (UV) light from the Sun, converting the UV energy into heat.
- The ozone layer **protects the Earth against most UV coming from the sun**.

MESOSPHERE

- The mesosphere is the third highest layer of Earth's atmosphere
- The region above the stratosphere is called the mesosphere.
- Mesosphere: 50 to 80 km (31 to 50 miles)
- It extends upward to a height of about 85 km (53 miles) above our planet.
- Temperatures once again grow colder as you rise up through the mesosphere.
- The coldest temperatures in earth's atmosphere, about -90° c
- (-130° f), are found near the top of this layer.
- The layer between the stratosphere and mesosphere is called stratopause.
- As the altitude increases the temp decreases.

THERMOSPHERE

- The thermosphere is the second-highest layer of Earth's atmosphere.
- The thermosphere lies above the mesopause,
- Thermosphere: 80 to 700 km (50 to 440 miles)
- **Karman line** is the boundary between Earth's atmosphere and outer space.
- Karman line lies 100 km above the mean sea level.
- in which temperatures again increase with height.
- As the altitude increases temp also the increases.
- It is this layer where many of the satellites orbiting the earth are present.
- The layer between the mesosphere and thermosphere is called mesopause.

EXOSPHERE

- The exosphere is the outermost layer of Earth's atmosphere (i.e. the upper limit of the atmosphere).
- Exosphere: 700 to 10,000 km (440 to 6,200 miles)
- It extends from the thermopause, at the top of the thermosphere at an altitude of about 700 km above sea level, to about 10,000 km (200 mies; 33,000,000 ft).
- The layer between the thermosphere and exosphere is called thermopause.

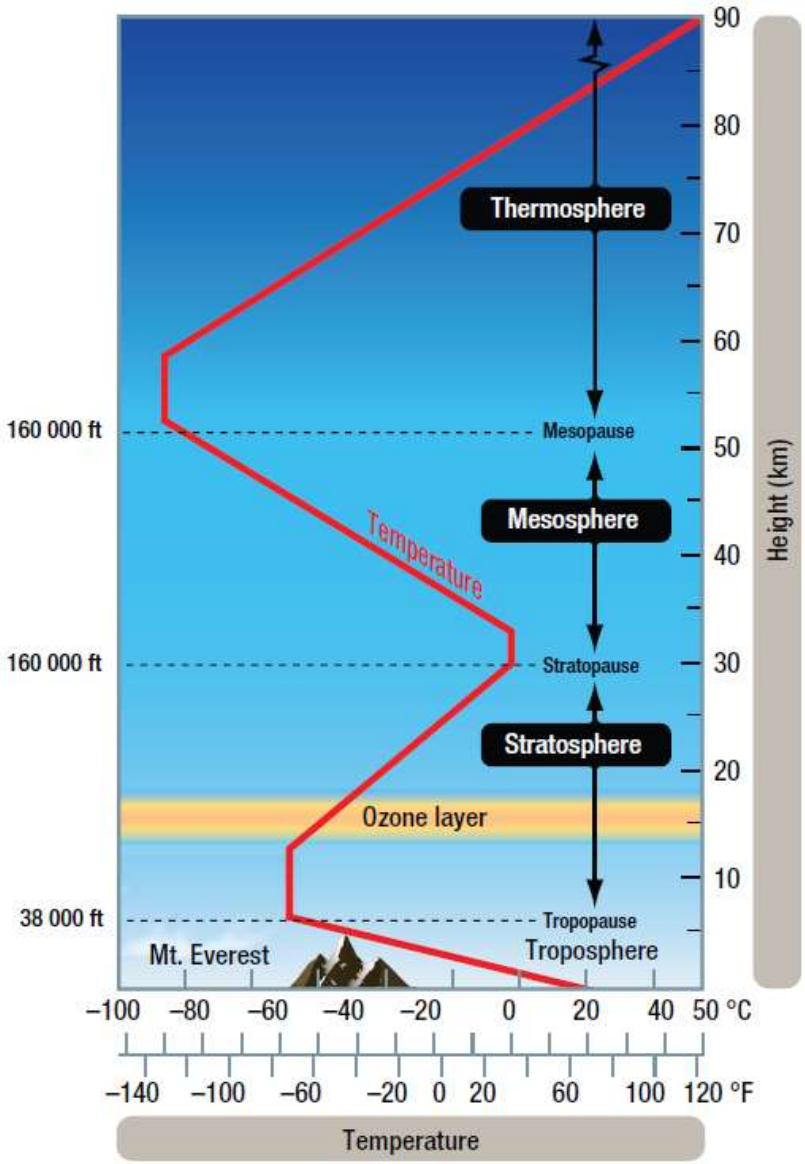


Figure 1-6. The atmospheric layers with temperature changes depicted by the red line.

The International Standard Atmosphere (ISA)

- The **International Standard Atmosphere** (**ISA**) is a static atmospheric model of how the pressure, temperature, density, and viscosity of the Earth's atmosphere change over a wide range of altitudes or elevations.
- It has been established to provide a common reference for temperature and pressure and consists of tables of values at various altitudes

- As atmospheric conditions vary around the world due to changes in the properties of the atmosphere. It was internationally agreed to have a Standard Atmosphere covering temperature, pressure and density for varying altitudes, in order to compare aircraft performance and calibrate aircraft instruments.
- The **International Civil Aviation Organization** (**ICAO**) is a specialized agency of the United Nations that changes the principles and techniques of international air navigation, and fosters the planning and development of international air transport to ensure safe and orderly growth

- **The International Standard Atmosphere (ISA) was agreed by the International Civil Aviation Organisation (ICAO) and set at mean sea level with values of.**

- Pressure : 1013.25 millibar (mb)
  14.69 PSI
  29.92 inches of mercury or 76 cm of mercury

- Density : 1.225 kg/m3
  0.077 lbs/ft3

- Temperature : 15°C
  59°F
  288K

- **International Civil Aviation Organization (ICAO)**
- **International Organization for Standardization (ISO)**
- **The International Standard Atmosphere (ISA)**

ALTITUDE	TEMPERATURE		PRESSURE		DENSITY	
Feet	°F	°C	psi	hPa	slug/ft³	kg/m³
Sea Level	59	15	14.67	1013.53	0.002378	1.23
1000	55.4	13	14.17	977.16	0.002309	1.19
2000	51.9	11	13.66	941.82	0.002242	1.15
3000	48.3	9.1	13.17	908.11	0.002176	1.12
4000	44.7	7.1	12.69	874.94	0.002112	1.09
5000	41.2	5.1	12.05	843.07	0.002049	1.06
6000	37.6	3.1	11.78	812.2	0.001988	1.02
7000	34	1.1	11.34	781.85	0.001928	0.99
8000	30.5	-0.9	10.92	752.91	0.001869	0.96
9000	26.9	-2.8	10.5	724.28	0.001812	0.93
10 000	23.3	-4.8	10.11	697.06	0.001756	0.9
15 000	5.5	-14.7	8.3	571.82	0.001496	0.77
20 000	-12.3	-24.6	6.75	465.4	0.001267	0.65
25 000	-30.2	-34.5	5.46	376.01	0.001066	0.55
30 000	-48	-44.4	4.37	301.3	0.000891	0.46
35 000	-65.8	-54.3	3.47	238.42	0.000738	0.38
40 000	-69.7	-56.5	2.72	187.54	0.000587	0.3
45 000	-69.7	-56.5	2.15	147.48	0.000462	0.24
50 000	-69.7	-56.5	1.68	115.83	0.000362	0.19

Figure 1-7. The International Standard Atmosphere.

LAPSE RATE

- The **lapse rate** is the rate at which an atmospheric variable, normally **temperature** in Earth Atmosphere, falls with Altitude.
- The temperature lapse rate below the tropopause is **2°C per 1000 ft.**

THANK YOU

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