AIRCRAFT TECHNICAL BOOK COMPANY

CAT-A

AVIATION MAINTENANCE TECHNICIAN CERTIFICATION SERIES

BASIC AERODYNAMICS

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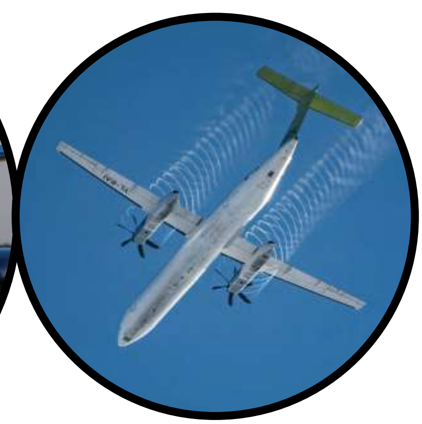

COMPLIANT WITH EASA PART 66/147

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VERSION	EFFECTIVE DATE	DESCRIPTION OF REVISION(S)
001	2018.06	Module creation and release.
001.1	2023.04	Inclusion of Measurement Standards for clarification, page iv. Minor appearance and format updates.
002	2024.04	Regulatory update for EASA 2023-989 Compliance.

Module was reorganized based upon the EASA 2023-989 subject criteria. Enhancements included in this version 002 are:

8.1 *Atmospheric Density* - added content.
8.1 *Water Content* - added content.
8.2 *Free Stream Flow* - rewrite.
8.2 *Aerodynamic Contamination* - added content.
8.3 *Aircraft Performance* - rewrite.
8.4 *Shock Waves* - added new figure.

BASIC AERODYNAMICS

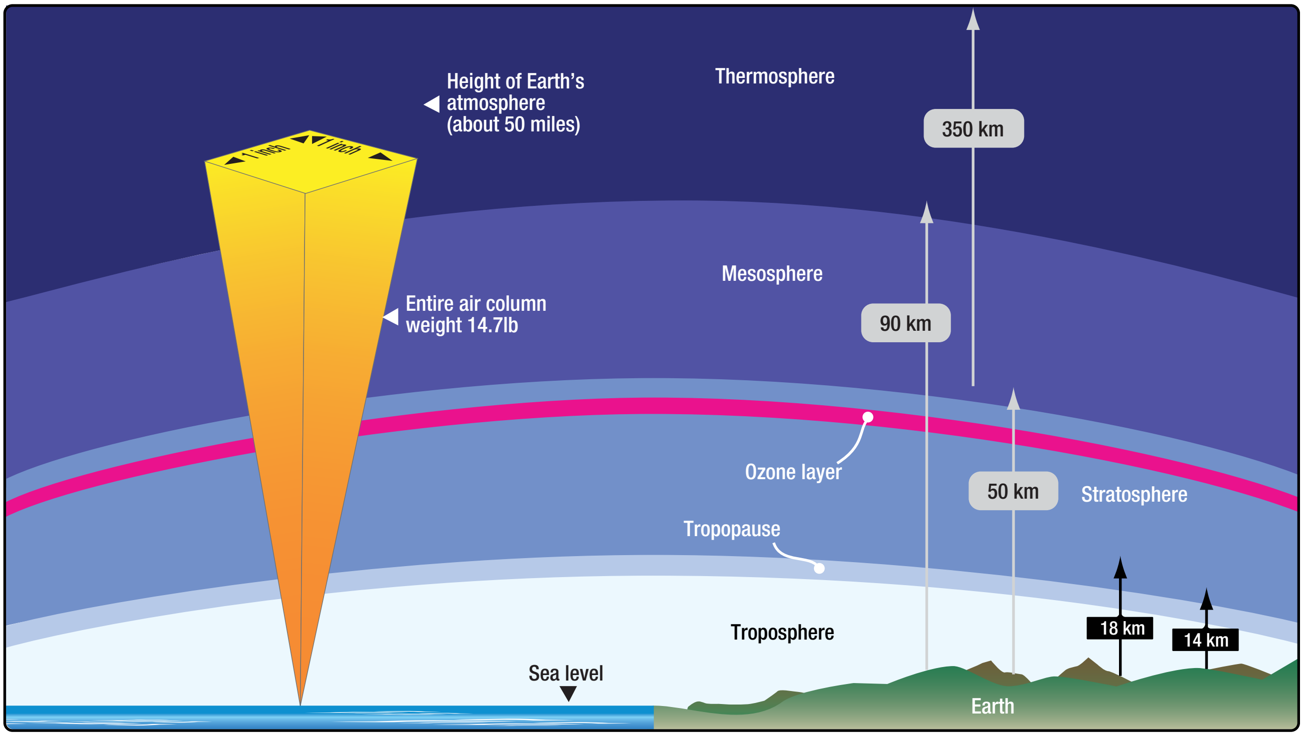

Figure 1-1. The weight exerted by a 1 square inch column of air stretching from sea level to the top of the atmosphere is what is measured when it is said that atmospheric pressure is equal to 14.7 pounds per square inch.

run out. Atmospheric pressure pushing down on the mercury in the open container tries to make the mercury stay in the tube. At some point these two forces (gravity and atmospheric pressure) will equilibrate out and the mercury will stabilize at a certain height in the tube. **Figure 1-2** demonstrates this point.

A second means of measuring atmospheric pressure is with an aneroid barometer. This mechanical instrument is a much better choice than a mercury barometer for use on airplanes. Aneroid barometers, or altimeters, are used to indicate altitude in flight. The calibrations are made in thousands of feet rather than in psi or inches of mercury. For example, the standard pressure at sea level is 29.92 "Hg, or 14.7 psi. At 10 000 feet above sea level, standard pressure is 20.58 "Hg, or 10.10 psi. Altimeters are calibrated so that if the pressure exerted by the atmosphere is 10.10 psi, the altimeter will point to 10 000 ft. [**Figure 1-3**]

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.

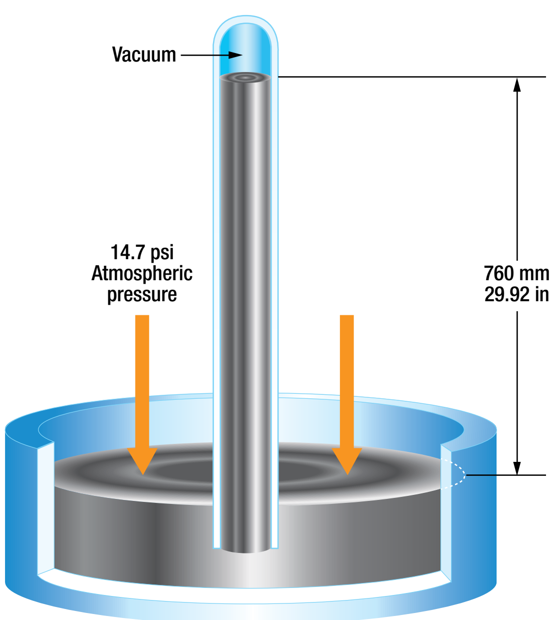

Figure 1-2. Atmospheric pressure as inches of mercury.

Figure 1-3. An airplane's altimeter is an aneroid barometer.

DENSITY

Density is weight per unit of volume. 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.

Thus, 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.

TEMPERATURE AND ALTITUDE

Temperature variations in the atmosphere are of concern to aviators. Weather systems produce changes in temperature near the earth's surface. Temperature also changes as altitude is increased. The troposphere is the lowest layer of the atmosphere. On average, it ranges from the earth's surface to about 38 000 feet above it. Over the poles, the troposphere extends to only 25 000 - 30 000 feet and, at the equator, it may extend to around 60 000 feet. This oblong nature of the troposphere is illustrated in **Figure 1-4**.

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.

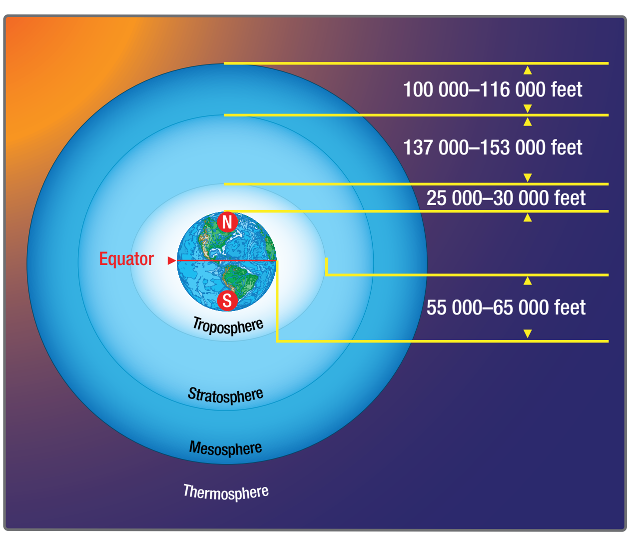

Figure 1-4. The troposphere extends higher above the earth's surface at the equator than it does at the poles.

Above the tropopause lies the stratosphere. Temperature increases with altitude in the stratosphere to near 0°C before decreasing again in the mesosphere, which lies above it. The stratosphere contains the ozone layer that protects the earth's inhabitants from harmful UV (Ultraviolet) rays. Some civilian flights and numerous military flights occur in the stratosphere. **Figure 1-5** diagrams the temperature variations in different layers of the atmosphere.

Density varies inversely with temperature or, as temperature increases, air density decreases. This phenomenon explains why on very warm days, aircraft takeoff performance decreases. The air available for combustion is less dense. Air with low density contains less total oxygen to combine with the fuel.

WATER CONTENT

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

1. Absolute humidity is the weight of water vapor in a unit volume of air.
2. 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.

Assuming that the temperature and pressure remain the same, the density of the air varies inversely with the humidity. On damp days, the air density is less than on dry days. For this reason, an

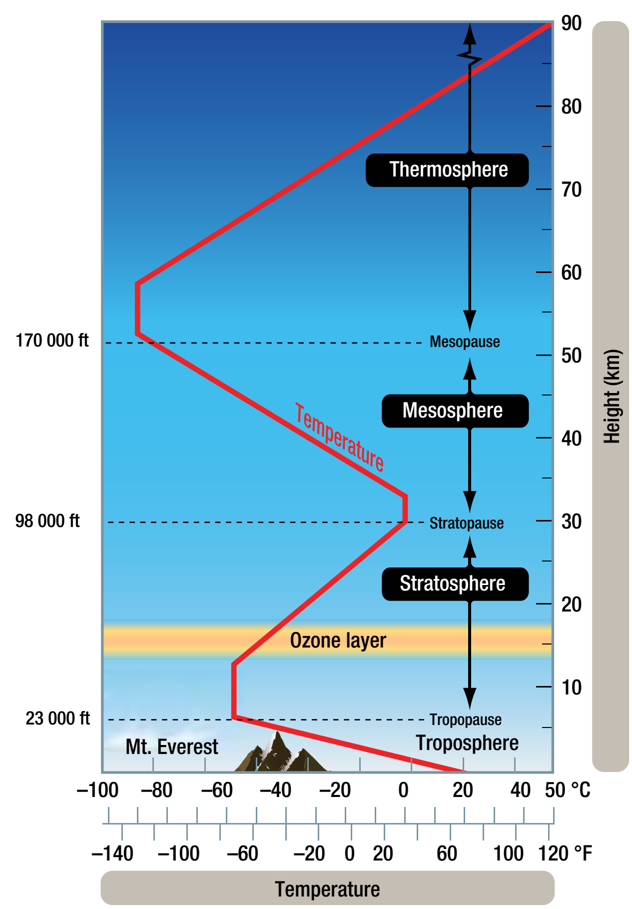

Figure 1-5. The atmospheric layers with temperature changes depicted by the red line.

aircraft requires a longer runway for takeoff on damp days than it does on dry days. By itself, water vapor weighs approximately five-eighths as much as an equal amount of perfectly dry air. Therefore, when air contains water vapor, it is not as heavy as dry air containing no moisture.

As a result of evaporation, the atmosphere always contains some moisture in the form of water vapor. The moisture in the air is called the humidity of the air.

Fog and humidity both affect the performance of an aircraft. In flight, at cruising power, the effects are small and receive no consideration. During takeoff, however, humidity has important effects. Two things are done to compensate for the effects of humidity on takeoff performance. Since humid air is less dense than dry air, the allowable takeoff gross weight of an aircraft is generally reduced for operation in areas that are consistently humid. Second, because the power output of reciprocating engines is decreased by humidity, the manifold pressure may need to be increased above that recommended for takeoff in dry air in order to obtain the same power output.

DEW POINT

The dew point is the temperature to which humid air must be cooled at constant pressure to become saturated. If the temperature drops below the dew point, condensation occurs. People who wear eyeglasses have experience going from cold outside air into a warm room and having moisture collect quickly on their glasses. This happens because the glasses were below the dew point temperature of the air in the room. The air immediately in contact with the glasses was cooled below its dew point temperature, and some of the water vapor was condensed out.

INTERNATIONAL STANDARD ATMOSPHERE (ASA)

The atmosphere is never at rest. Pressure, temperature, humidity, and density of the air are continuously changing. To provide a basis for theoretical calculations, performance comparisons and instrumentation parity, standard values for these and other characteristic of the atmosphere have been developed. International Civil Aviation Organization (ICAO), International Organization for Standardization (ISO), and various governments establish and publish the values known as the International Standard Atmosphere. [**Figure 1-6**]

ALTITUDE	TEMPERATURE		PRESSURE		DENSITY	
Feet	°F	°C	psi	hPa	slug/ft^3	kg/m^3
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 1-6. The International Standard Atmosphere.