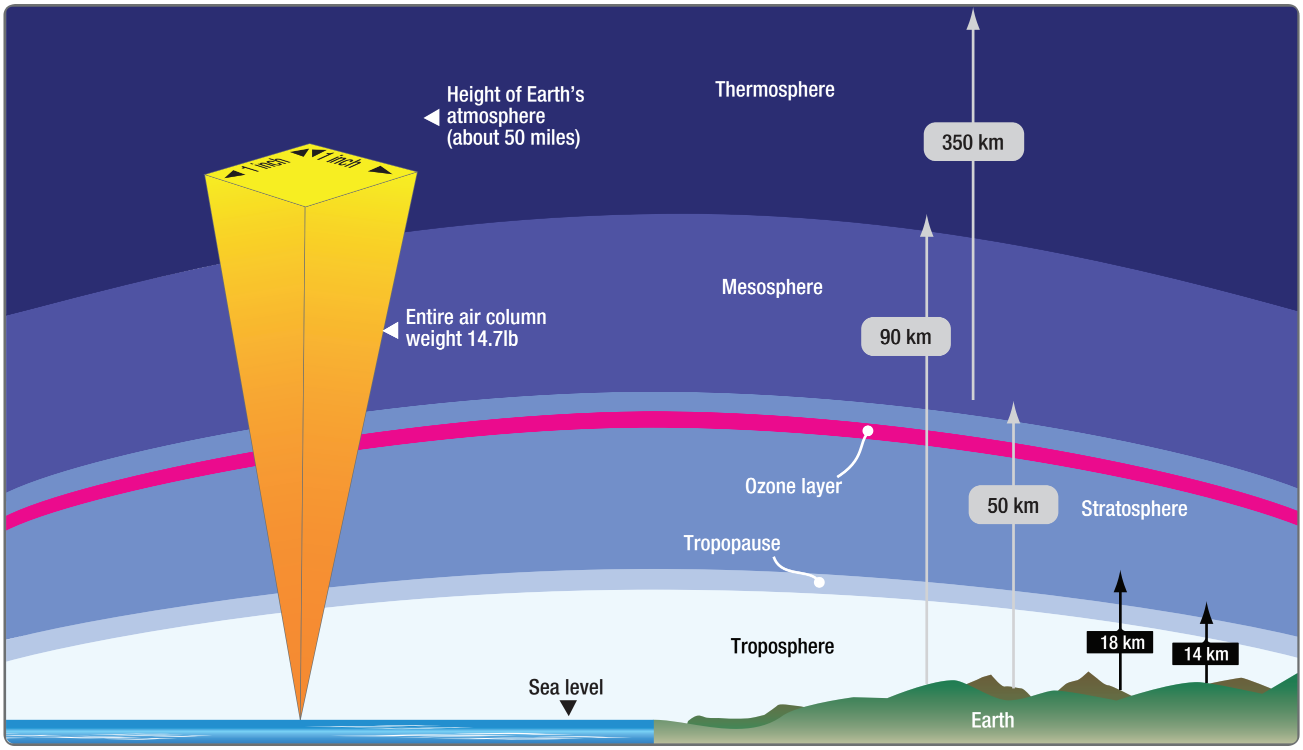

Figure 1-1. The weight exerted by a 1 square inch column of air stretching from sea level to the top of the atmosphere is what is measured when it is said that atmospheric pressure is equal to 14.7 pounds per square inch.

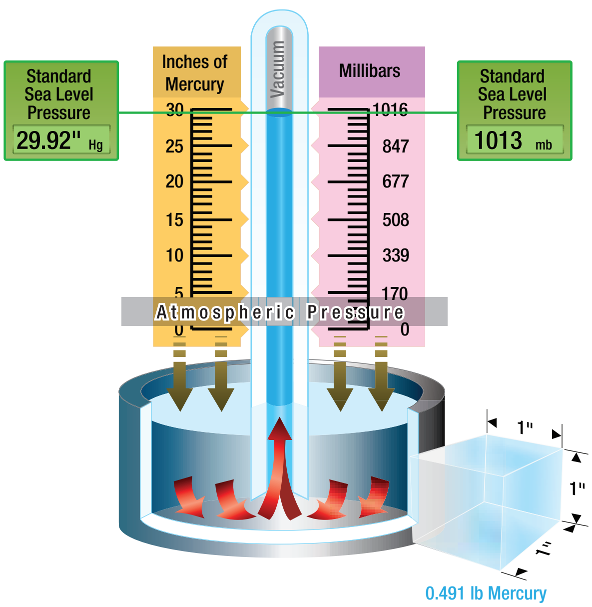

Figure 1-2. Barometer used to measure atmospheric pressure.

Aviators often interchange references to atmospheric pressure between linear displacement (e.g., inches of mercury) and units of force (e.g., psi). Over the years, meteorology has shifted its use of linear displacement representation of atmospheric pressure to units of force. The unit of force nearly universally used today to represent atmospheric pressure in meteorology is the hectopascal (hPa). A pascal is a SI metric unit that expresses force in Newtons per square meter. A hectoPascal is 100 Pascals. 1 013.2 hPa is equal to 14.7 psi which is equal to 29.92 Hg. (***Figure 1-3***)

Atmospheric pressure decreases with increasing altitude. The simplest explanation for this is that the column of air that is weighed is shorter. How the pressure changes for a given altitude is shown in ***Figure 1-4***. The decrease

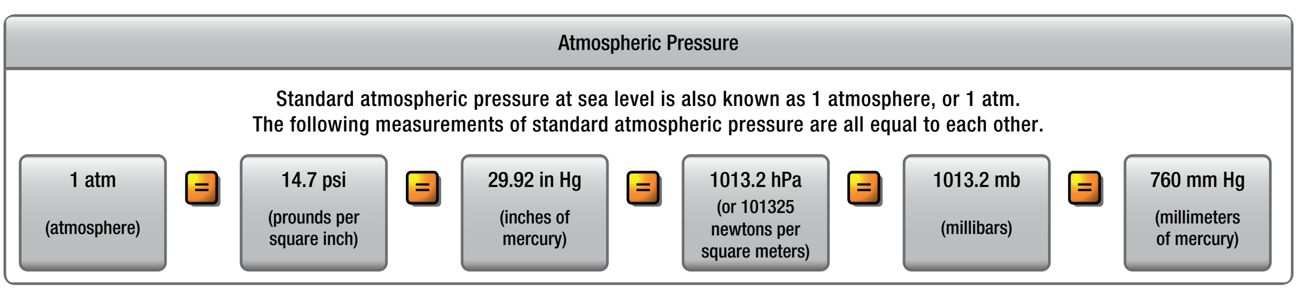

Figure 1-3. Various equivalent representations of atmospheric pressure at sea level.

in pressure is a rapid one and, at 50 000 feet, the atmospheric pressure has dropped to almost one-tenth of the sea level value.

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.

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.

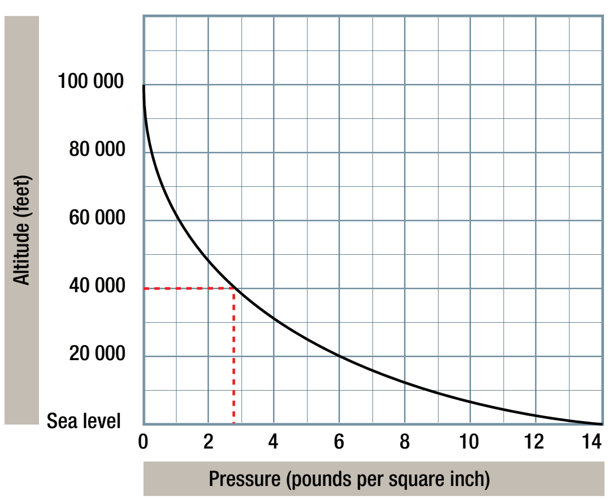

Figure 1-4. Atmospheric pressure decreasing with altitude. At sea level the pressure is 14.7 psi, while at 40 000 feet, as the dotted lines show, the pressure is only 2.72 psi.

HUMIDITY

Humidity is the amount of water vapor in the air. 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.

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 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.

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 1-5***.

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.

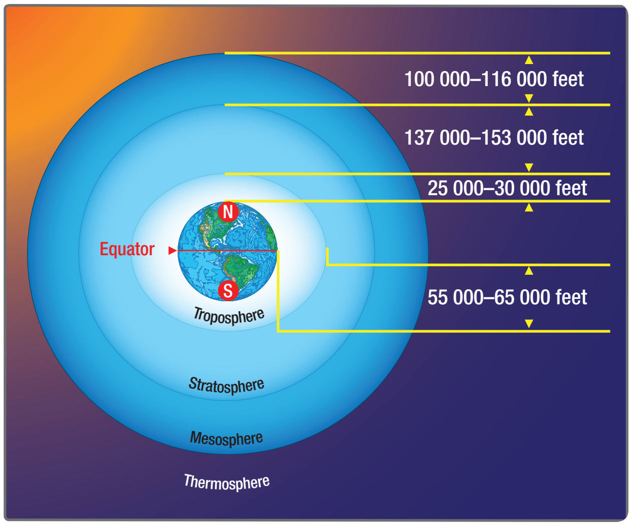

Figure 1-5. The troposphere extends higher above the earth's surface at the equator than it does at the poles.

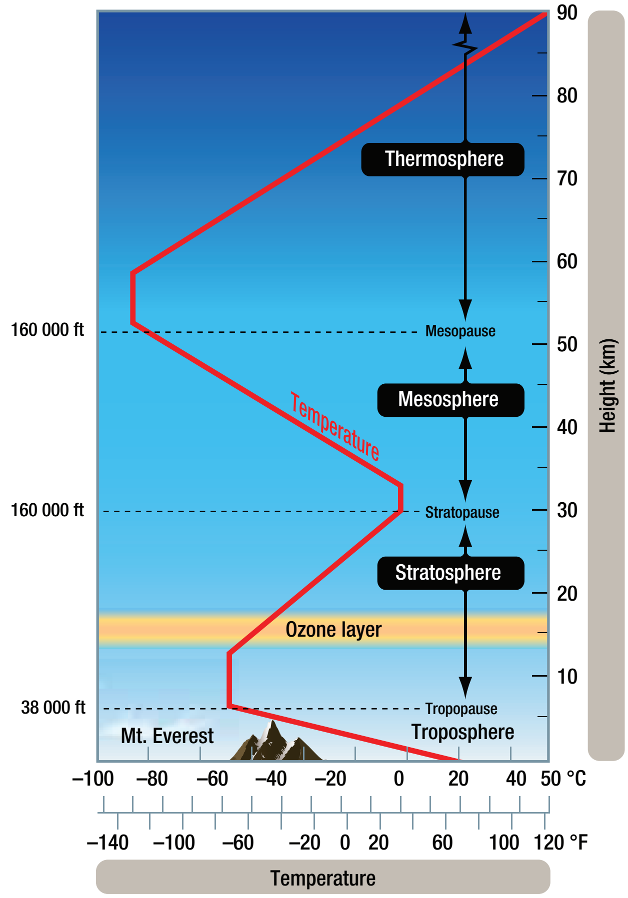

Figure 1-6. The atmospheric layers with temperature changes depicted by the red line.

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 1-6*** diagrams the temperature variations in different layers of the atmosphere.

As stated, 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.

INTERNATIONAL STANDARD ATMOSPHERE

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 1-7***)

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 1-7. The International Standard Atmosphere.

Question: 1-1
Atmospheric pressure is measured with an instrument called a __________________.

Question: 1-2
In which layer of the atmosphere does most civilian aviation take place?

Question: 1-3
In what atmospheric conditions will an aircraft perform the best?

Question: 1-4
If air temperature is 20°C at sea level; what will be its approximate temperature at 30 000 feet altitude?

Question: 1-5
What are the 4 primary factors which effect the atmosphere?

Question: 1-6
What rule making body determines standards for studying the atmosphere?