Altitude and Atmospheric Pressure

Students will gain a basic understanding of math applications used in flight to include atmospheric pressure and altitude. Students will solve a series of problems using this information.

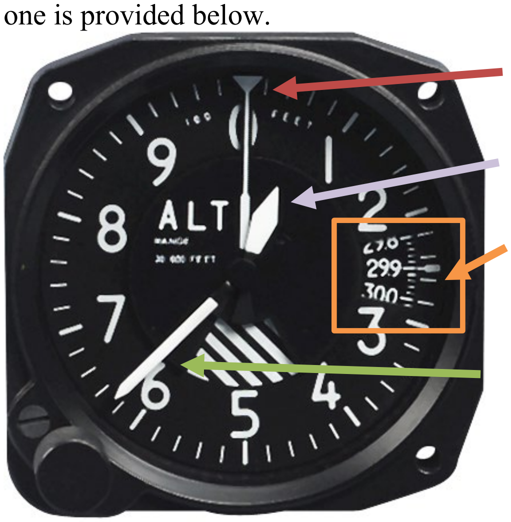
LESSON PLAN

Lesson Objectives

The students will:
- Be introduced to formulas used in flight related atmospheric pressure in relation to altitude
- Learn how altimeters reference altitude over sea level instead of ground level
- Learn how to read an analog altimeter

Goal
In this lesson, students will gain an understanding of common calculations performed by flight personnel.

Altimeters
Altimeters are devices that measure altitude. Altitude is generally a relative value, which means that it depends on whether one is talking about 5000' above sea level or ground level. The standard way to discuss altitude is ***above sea level***. At sea level, 0', the atmospheric pressure is measured as 29.92" Hg. Reading an altimeter is fairly simple, an image of one is provided below.



Grade Level: 9 - 12

Ohio Learning Standards/Science (2018)
Expectation of Learning
Nature of Science

Ohio Learning Standards/Mathematics (2017)

Numbers & Quantity Standards
N.Q.1: Use units to understand problems
Algebra
A.SSE.1: Interpret expressions in its context
A.SSE.3: Choose and produce equivalent expressions
A.CED.4: Rearrange formulas for quantities of interest
A.REI.1: Explain each step in solving an equation
A.REI.3: Solve linear equations

Materials Required

- One worksheet per student (attached)
- Pencil or pen

Altitude and Atmospheric Pressure
Pressure is measured in many different units, and the SI unit for pressure is the pascal (Pa or N/m^2). However, pressure can also be measured in other units as well. In relation to aviators, an inch of liquid metal mercury (1" Hg) can be related to altitude. For each 1000 ft that an aircraft ascends, atmospheric pressure will decrease by 1" Hg. This means that it is possible to calculate the change in altitude by a change in pressure.

Formulas and Examples

Since we know that the decrease in pressure results in an increase in altitude, we know the two are related, and since +1" Hg corresponds to -1000 ft elevation, here's our set up:
We want to relate the change in pressure and altitude, so we identify some variables.

$$Pressure_{final} - Pressure_{Initial} = Change\ in\ Pressure = \Delta P$$
$$Altitude_{Final} - Altitude_{inital} = Change\ in\ Altitude = \Delta A$$

We need to make sure that we are keeping the units with the change in pressure (which is in inches Hg), and the change in altitude (in feet), so that we may use a converting factor. We can use the information that the altitude ***decreases by 1000 ft per 1"Hg***, so let us introduce a conversion factor, *k*, to relate ΔP to ΔA.

$$k\Delta P = \Delta A$$

We can actually solve for k using the bold information.

$$k\Delta P = \Delta A \xrightarrow{divide\ both\ sides\ by\ \Delta P} k = \frac{\Delta A}{\Delta P} \xrightarrow{input\ values} k = \frac{-1000ft}{1"\ Hg}$$

So our model will look like this:

$$\Delta P * -1000\frac{ft}{1"\ Hg} = \Delta A$$

Example 1: If the air pressure changes from 30.18" Hg to 29.76" Hg, what is the change in elevation?

Solution: We have an initial pressure of 30.18 "Hg and a final pressure of 29.76" Hg, we can then calculate ΔP.

$$\Delta P = P_{final} - P_{initial} = 29.76"\ \text{Hg} - 30.18"\ \text{Hg} = -0.42"\ Hg$$

Now we can use the relationship we developed to get the change in altitude (ΔA).

$$\Delta A = \Delta P * -1000\frac{ft}{1"Hg} = -0.42\ "\ Hg\ * \ -1000\ \frac{ft}{1"Hg} = 420\ ft$$

So the answer is 420 ft higher. This makes sense since the pressure decreases as you go up, the plane should be higher.

Example 2: At sea level (0 ft), the air pressure measures 29.92" Hg. Calculate the air pressure a commercial airliner would experience at 13,500 ft.

Solution: We are looking for the final pressure, so we cannot solve quite yet since we don't know ΔP. We are given enough information for ΔA though!

$$\Delta A = A_{final} - A_{initial} = 13{,}500\ ft - 0\ ft = 13{,}500\ ft$$

Now, we can use our relationship we developed to get the change in pressure (ΔP).

$$\Delta A = \Delta P * -1000\frac{ft}{1"Hg} = 13{,}500\ ft = \Delta P * -1000\frac{ft}{1"\ Hg} \xrightarrow{divide\ by -1000\frac{ft}{1"Hg}} \Delta P = \frac{13500ft}{-1000ft}\text{Hg} = \Delta P = -13.5\ Hg$$

Then solving from $\Delta P = P_{final} - P_{inital}$

$$\Delta P = P_{final} - P_{initial} \xrightarrow{add\ P_{initial}\ on\ both\ sides} \Delta P + P_{initial} = P_{final} \Rightarrow -13.5\text{ Hg} + 22.92"\text{ Hg} = 9.42\ "\ Hg$$

NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE™

NAME: ____________________

MATHEMATICS OF FLIGHT: ALTITUDE AND ATMOSPHERIC PRESSURE

$$Pressure_{final} - Pressure_{Initial} = Change\ in\ Pressure = \Delta P$$
$$Altitude_{Final} - Altitude_{inital} = Change\ in\ Altitude = \Delta A$$

$$\Delta P * -1000 \frac{ft}{1"\ Hg} = \Delta A$$

Exercise 1
Settings changed from 29.25” Hg to 29.85” Hg. What is the approximate change in altitude?

Exercise 2
Setting changed from 30.30” Hg to 29.51” Hg. What is the approximate change in altitude?

Exercise 3
In Dayton OH, home of the National Museum of the United States Air Force, the air pressure measures 29.78” Hg, and has an elevation of 738 ft above sea level. Calculate the elevation of an aircraft that reports a pressure reading of 27.70” Hg while over Dayton.

Exercise 4
The Lockheed U-2 was a high altitude reconnaissance aircraft which was able to fly at 70,000 ft above sea level. Use the previously found value of 29.92” Hg for sea level (0ft) to calculate the air pressure at 70,000 ft. Does this answer make sense? Do you think something is wrong with our model? (https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/195974/lockheed-u-2a/)

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$$\Delta P * -1000 \frac{ft}{1"\ Hg} = \Delta A$$

Exercise 1

Settings changed from 29.25" Hg to 29.85" Hg. What is the approximate change in altitude?

ΔA= -600 ft. ΔA is negative so the aircraft descended.

Exercise 2

Setting changed from 30.30" Hg to 29.51" Hg. What is the approximate change in altitude?

ΔA= 790 ft. ΔA is positive so the aircraft ascended.

Exercise 3

In Dayton OH, home of the National Museum of the United States Air Force, the air pressure measures 29.78" Hg, and has an elevation of 738 ft above sea level. Calculate the elevation (above sea level) of an aircraft that reports a pressure reading of 27.70" Hg while over Dayton.

ΔA=2080'. $\Delta A + A_{Dayton} = A_{final}$ = 2080' + 738' = 2813 ft.

Exercise 4

The Lockheed U-2 was a high altitude reconnaissance aircraft which was able to fly at 70,000 ft above sea level. Use the previously found value of 29.92" Hg for sea level (0ft) to calculate the air pressure at 70,000 ft. Does this answer make sense? Do you think something is wrong with our model?

ΔP = -70" Hg. $\Delta P + P_{sea} = P_{U\text{-}2}$ = -70" Hg + 29.92" Hg = -40.08" Hg. No, this answer does not make sense. Yes the model is incorrect as the air pressure change is nonlinear with altitude at high elevations.