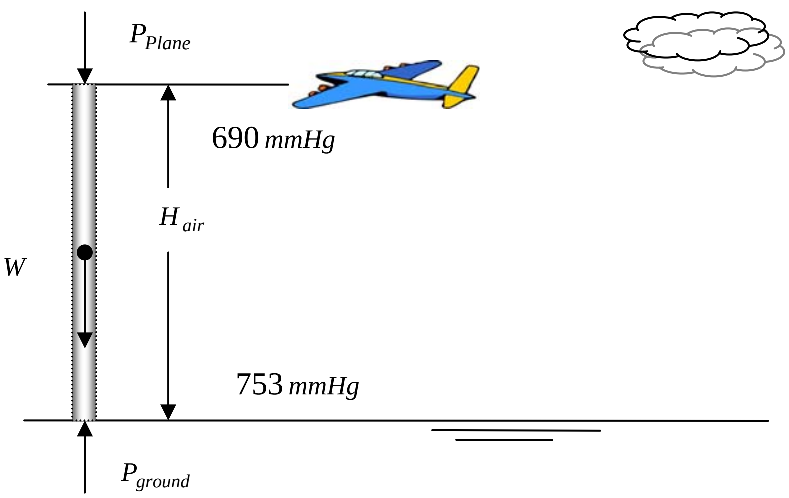
Basic Concepts of Thermodynamics

1-51 The basic barometer can be used as an altitude-measuring device in airplanes. The ground control reports a barometric reading of 753mmHg while the pilot's reading is 690 mmHg. Estimate the altitude of the plane from ground level if the average air density is 1.20kg/m^3 and g=9.8m/s^2.

Step 1: Draw a diagram to represent the system



Step 2: Write out what you need to solve for
The altitude of the airplane from ground level.

Step 3: State what you have known and your assumptions (you may have to add to your list of assumptions as you proceed in the problem)

1) The barometric readings of the ground and the airplane
2) The air density, the mercury density
3) Homogeneous gravitational acceleration
4) Assuming there is an air column between the ground and the airplane.

Step 4: Prepare a table of properties

Parameter	Symbol	Properties
Air density	ρ_{air}	1.20 kg/m^3
Mercury density	$\rho_{mercury}$	13,600 kg/m^3
Gravitational constant	g	9.8 m/s^2
Ground barometer	h_{ground}	753 $mmHg$
Airplane barometer	h_{plane}	690 $mmHg$

Step 5: Solve

First of all, calculate the atmospheric pressures at the location of the ground level and the plane according to the definition of the barometer.

$$P_{plane} = \rho_{mercury} g h_{plane} = (13.600 kg/m^3)(9.8 m/s^2)(0.690 m)\left[\frac{1N}{1kg*m/s^2}\right]\left[\frac{1kPa}{1000N/m^2}\right]$$

$$= 91.96 kPa$$

$$P_{ground} = \rho_{mercury} g h_{ground} = (13.600 kg/m^3)(9.8 m/s^2)(0.753 m)\left[\frac{1N}{1kg*m/s^2}\right]\left[\frac{1kPa}{1000N/m^2}\right]$$

$$= 100.36 kPa$$

Imaging there is an air column between the airplane the ground and taking a force balance for this imaginary air column.

$$W_{air} + P_{plane} * A = P_{ground} * A \Rightarrow \rho_{air} g H_{air} * A = (P_{ground} - P_{plane}) * A$$

$$\Rightarrow H_{air} = \frac{P_{ground} - P_{plane}}{\rho_{air} g}$$

Substituting the values into above equation gives the final solution.

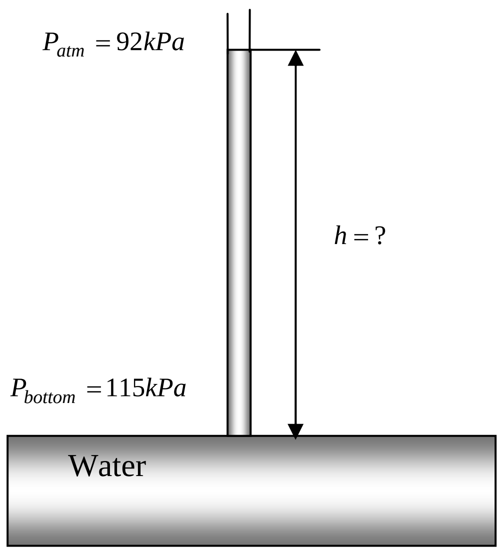
$$H_{air} = \frac{(100.36 - 91.96) kPa}{(1.20 kg/m^3)(9.8 m/s^2)}\left[\frac{1000 N/m_2}{1kPa}\right]\left[\frac{1kg*m/s^2}{1N}\right] = 714.3 m$$

Step 6: Conclusion statement

The altitude of the plane from the ground level is 714.3m.

1-55 A glass tube is attached to a water pipe. If the water pressure at the bottom of the glass tube is 115kPa and the local atmospheric pressure is 92kPa, determine how high the water will rise in the tube, in meters. Assume g=9.8m/s^2 at that location and take the density of water to be 1000 kg/m^3.

Step 1: Draw a diagram to represent the system



Step 2: Write out what you need to solve for

Determine how many meters the water will rise in the tube.

Step 3: State what you have known and your assumptions

1) The water pressure at the bottom of the tube is 115kPa.
2) The local atmospheric pressure is 92kPa.
3) The density of water is 1000kg/m^3.
4) The gravitational acceleration at the location is g=9.8 m/s^2.
5) There is a pressure balance at the bottom of the tube

Step 4: Prepare a table of properties

Parameter	Symbol	Properties
Bottom pressure	P_{bottom}	$115\,kPa$
Atmospheric pressure	P_{atm}	$92\,kPa$
Gravitational accele.	g	$9.8\,m/s^2$
Water density	ρ	$1000\,kg/m^3$

Step 5: Solve (usually start by writing the force or pressure equilibrium)

Eq1 is the pressure balance equation at the bottom of the tube.

$$P_{bottom} = P_{atm} + (\rho g h)_{tube} \qquad \text{(Eq1)}$$

Rearranging and re-expressing Eq1 to get the solving equation for h.

$$h = \frac{P_{bottom} - P_{atm}}{\rho g} \quad \text{(Eq2)}$$

Substituting in values into Eq2 gives the solution for the final height of water in the tube.

$$h = \frac{(115-92)[kPa]}{(1000kg/m^3)(9.8m/s^2)} = \frac{23}{9800}\frac{kPa}{kg/m^3 * m/s^2}[\frac{1kg * m/s^2}{1N}][\frac{1000N/m^2}{1kPa}]$$
$$= 2.345m$$

Step 6: Conclusion statement

The water will rise 2.345m in the tube.

1-63 The average temperature of the atmosphere in the world is approximated as a function of altitude by the relation

$$T_{atm} = 288.15 - 6.5z$$

Where T_{atm} is the temperature of the atmosphere in K and z is the altitude in km with z=0 at sea level. Determine the average temperature of the atmosphere outside an airplane that is cruising at an altitude of 12,000m.

Step 1: Write out what you need to solve for

The temperature of the atmosphere outside an airplane.

Step 2: State what you have known and your assumptions

1) The function of temperature related to the altitude.
2) The altitude of the cruising airplane is 12,000m
3) There is a function to be used, but it needs unit conversion

Step 3: Solve

Using the relation given, the average temperature of the atmosphere at an altitude of 12,000m is determined to be

$$T_{atm} = 288.15 - 6.5z = 288.15 - 6.5 * 12 = 210.15K$$

Change the absolute temperature into ordinary temperature with conversion expression.

$$T(°C) = T(K) - 273.15$$

$$T_{atm} = 210.15K = (210.15 - 273.15) = -63°C$$

Step 4: Conclusion statement

The temperature outside the airplane is –63ºC or 210.15 K