

# Mercury Manometer

A mercury manometer is shown in Illustration 1. A tube, closed at one end, is filled with mercury (atomic symbol Hg) and inverted (open end down) in a pool of mercury. The column of mercury in the tube is accelerated by gravity, exerting a downward force, causing mercury to flow out of the tube, creating a vacuum in the upper part of the tube. The outflow of mercury stops when the force due to the column's mass in earth's gravity is exactly offset by the force that the atmosphere exerts on the surface of the mercury pool. This height is independent of the size or shape of the column or the pool surface area.

Calculate the height of the column of mercury at 1013 milliBar<sup>1</sup> atmospheric pressure given the density of mercury  $d = 13.6 \text{ g/mL}$  and that acceleration due to gravity is  $g = 9.8 \text{ m/s}^2$ :  
The volume of a (cylindrical) column is the area times the height:

$$V = Ah$$

The mass of the column is the volume times the density:

$$m = Vd$$

The downward force of the column is mass times acceleration:

$$F = mg$$

The pressure is equal to the force per unit area:

$$P = F/A$$

$$= mg/A$$

$$= Vdg/A$$

$$= Ahdg/A$$

$$= hdg$$

$$h = P/dg$$

$$= 1013 \times 0.01 \times 100^2 / (13.6 / 1000 \times 1000 \times 9.8) = 0.7600 \text{ m} = 760 \text{ mm}$$

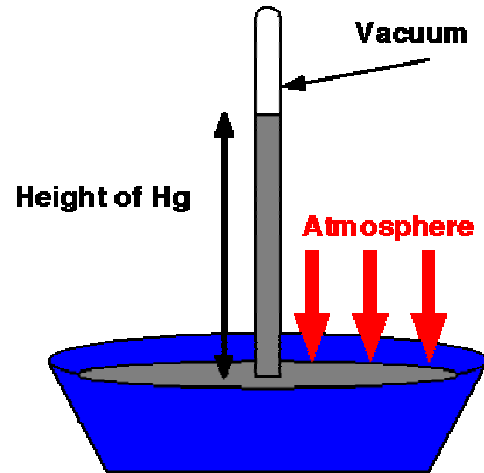


Illustration 1 Mercury Manometer

Calculate the fluctuation in the height of the column of mercury due to a maximum atmospheric pressure variation of 950 to 1050 milliBar:

$$h = P/dg$$

$$= 950 \times 0.01 \times 100^2 / (13.6 \times 9.8) = 713 \text{ mm}$$

$$= 1050 \times 0.01 \times 100^2 / (13.6 \times 9.8) = 788 \text{ mm}$$

$$\Delta h = 788 - 713 = 75 \text{ mm}$$

<sup>1</sup> **mil·li·bar** (ml-bär)

*n. Abbr. mb* A unit of atmospheric pressure equal to one thousandth ( $10^{-3}$ ) of a bar, or 0.01 Newtons/square centimeter. Standard atmospheric pressure at sea level is about 1,013 millibars.

## Resistivity

Resistivity (or *specific electrical resistance*) is a measure of a materials ability to resist electrical current. The formula for resistivity ( $\rho$ ) is usually based on the resistance of a sample of uniform cross section:

$$\rho = RS/L$$

where R is the electrical resistance, S is the cross sectional area and L is the length of the sample. Pencil lead (primarily graphite, clay or chalk and a binding substance) has a resistivity of  $5.351 \times 10^{-3}$  ohm-meters.

Calculate the resistance of a 0.5 mm radius pencil lead that is 75mm long:

$$\begin{aligned} R &= \rho \times L/S \\ &= 0.005351 \times 0.075 / \pi (0.5/1000)^2 \\ &= 6813 \text{ ohms} \end{aligned}$$

Calculate the resistance of a 75mm long column of mercury 5mm in radius if the resistivity of mercury is 95.783 microohm-cm

$$\begin{aligned} R &= \rho \times L/S \\ &= 95.783 / 1,000,000 / 100 \times 0.075 / \pi (5/1000)^2 \\ &= 9.14 \times 10^{-3} \text{ ohms} \end{aligned}$$

What would the resistance be if there was a device composed of 37.5mm of pencil lead in series with 37.5mm of mercury?

$$\sim 3407 \text{ ohms}$$

## Voltage Divider

A voltage divider is shown in Illustration 2. Assuming negligible output current ( $i_{out}$ ), the output voltage is given by:

$$V_{out} = V_{in} \times R_2 / (R_1 + R_2)$$

and the input current by:

$$i_{in} = V_{in} / (R_1 + R_2)$$

Calculate the resistance  $R_1$  required if the input voltage is 5 volts and the input current is to be limited to 2mA if  $R_2$  is reduced to zero ohms:

$$\begin{aligned} (R_1 + R_2) &= V_{in} / i_{in} \\ (R_1 + 0) &= 5 / 0.002 \\ R_1 &= 2500 \text{ ohms} \end{aligned}$$

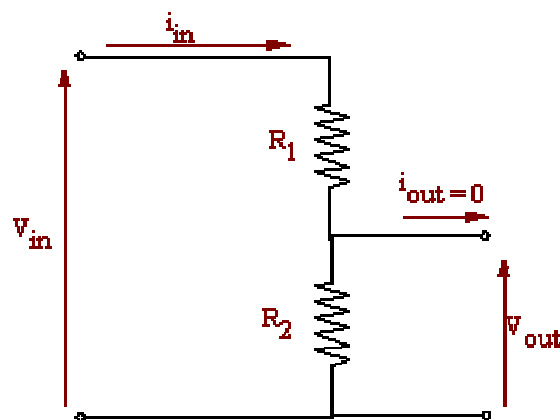


Illustration 2 Voltage Divider

Calculate the change in output voltage for an input voltage of 5 volts and  $R_1$  given by the above value if  $R_2$  varies from 0 to 6813 ohms:

$$\begin{aligned} V_{out} &= V_{in} \times R_2 / (R_1 + R_2) \\ &= 5 \times 0 / (2500 + 0) \end{aligned}$$

$$= 0 \text{ volts}$$

$$\begin{aligned} V_{\text{out}} &= V_{\text{in}} \times R_2 / (R_1 + R_2) \\ &= 5 \times 6813 / (2500 + 6813) \\ &= 3.66 \text{ volts} \end{aligned}$$

$$\Delta V = 3.66 - 0 = 3.66 \text{ Volts}$$

## **Synergy**

Sketch an instrument that would produce a voltage proportional to atmospheric pressure.