Barometers and Manometers

Fluid Statics – Lesson 3

Ansys

Introduction

- Barometers and manometers are devices used to measure pressure.
- The simplest forms of these devices use the height of a column of liquid with a known density to indicate the pressure.
- The height of the column is a consequence of the static force due to gravity acting on the liquid. We will examine how this works in the slides that follow.

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Barometer

- A barometer is traditionally an instrument used to measure atmospheric pressure.
- The pressure is indicated by the height of a liquid column in a vertical tube, the tube being oriented in the direction opposite gravity.
- A related instrument is the pressure altimeter, which uses the same principle as the barometer, except the column height indicates altitude above the earth (which requires calibrating the pressure reading with a known atmospheric pressure variation with altitude).

Barometer

Pressure altimeter used for aircraft altitude

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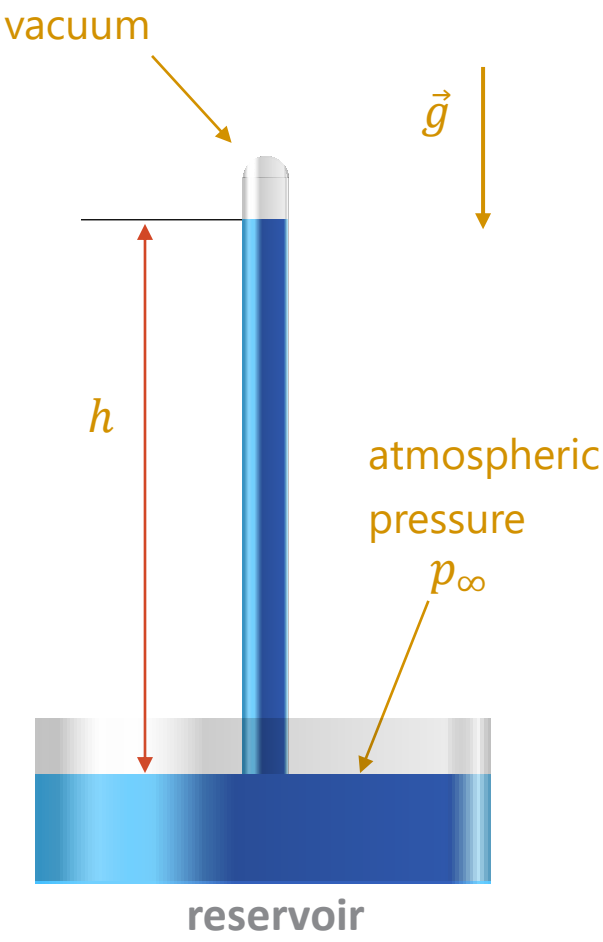
Barometric Analysis

- A diagram of a simple barometer is shown on the right.
- A tube filled with liquid sits in a reservoir of the liquid, the surface of which is exposed to the atmosphere.
- A vacuum forms in the space just above the meniscus of the liquid in the tube. As a result, no pressure force is exerted there.
- Therefore, the atmospheric pressure is directly related to the height of the column by the fluid statics equation:

$$p_\infty = \rho_l g h$$

- Notice that a heavier fluid (like liquid mercury) is desirable to make the column height reasonable. For example, if water were used, the height of the liquid would be 10.3 m for atmospheric pressure!



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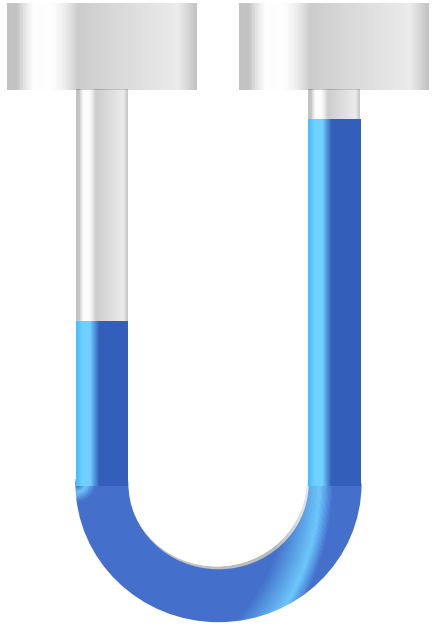
Manometer

- A manometer is a laboratory instrument which is used to determine the pressure difference between two locations.
- This is used primarily for flowrate measurements, as the pressure difference across a flow restriction can be directly related to the flow velocity by a relation called Bernoulli's Equation.



Manometer

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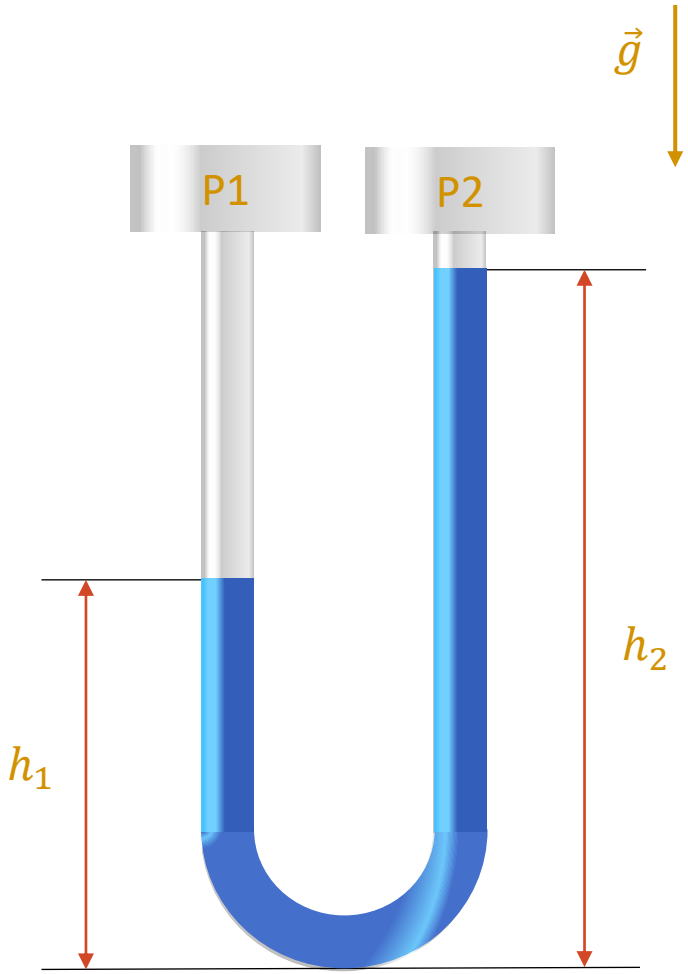
Manometer Analysis

- Consider a manometer filled with a liquid in a U-tube. We are measuring the difference in pressure P_1 and P_2.
- Manometers are typically used to measure flowrates of gases. Since the density of gases is usually orders of magnitude lower than that of the liquid, we can neglect the hydrostatic gradient in the gas and assume the pressures at the levels in both tubes are the gas pressures.
- From this assumption, it follows that the pressure difference is related to height difference by:

$$\Delta p = p_1 - p_2 = \rho_l g(h_2 - h_1)$$



U-tube manometer

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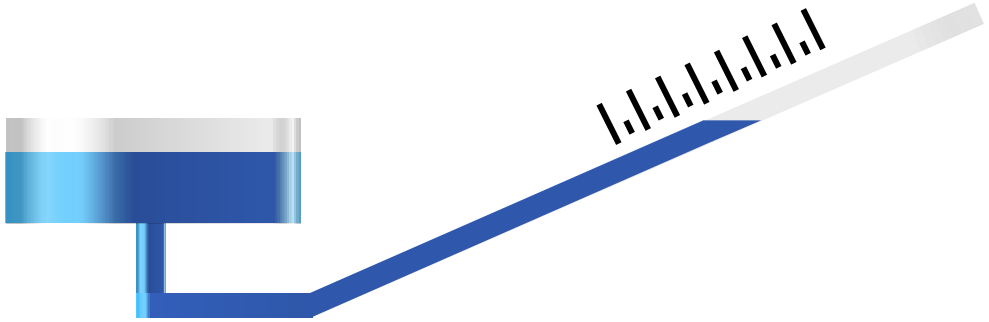
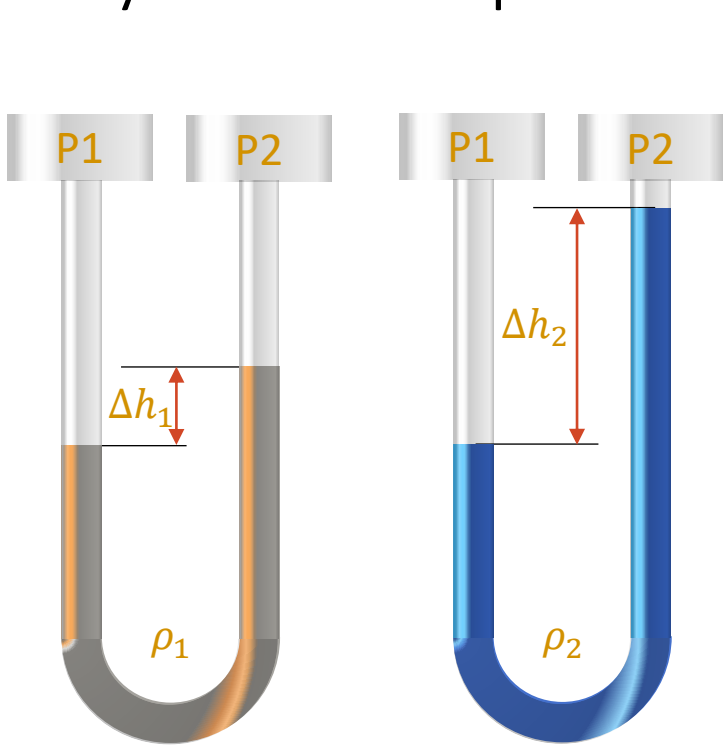
Improving the Sensitivity of the Manometer

- In flowrate measurement, large changes in flowrate may calibrate to small changes in liquid height differential. If this is the case, we can employ an inclined manometer, which permits a wider liquid indication range than a standard U-tube manometer.
- In addition, we could change the liquid density to further improve the sensitivity.



Inclined Manometer



$\rho_1 > \rho_2$ $\Delta h_1 < \Delta h_2$

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Summary

- We have examined two applications of fluid statics to pressure and flow measurement devices.
- The barometer measures pressure relative to the prevailing atmospheric pressure.
- The manometer measures pressure differences. These differences can be used to calculate flowrates for a calibrated orifice or nozzle.

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