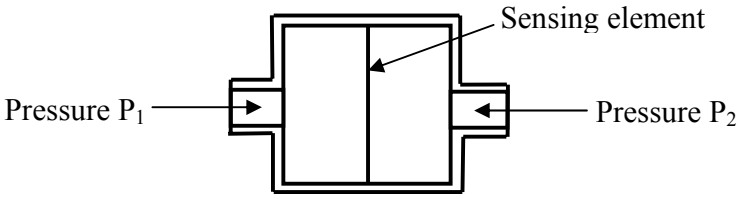
Tutorial 4

Pressure, flow and level measurements

Chapter 7 Pressure, Chapter 8 Flow and Chapter 9 Level

1. A U-tube manometer is used to measure the difference in pressure across an orifice plate in a pipe carrying water. Determine the pressure difference when the manometer indicates a head of 0.2 m of mercury. The density of water is 1.0 Mg/m^3 and relative density of mercury is 13.6 Mg/m^3. [Answers: 24.72 kN/m^2 or 0.247 bars]

2. The differential pressure transducer as shown in the following figure has the pressure P_1 = 5.0 bars absolute. If the other inlet pressure port is open to atmosphere, calculate the absolute, gauge and differential pressures sensed by the sensing element. Atmosphere can be taken as 1.013 bars.



3. The following table gives the results of the calibration of a 0 to 10 bar pressure gauge:

True pressure (bar)	0	2	4	6	8
Recoded pressure (bar)	0.05	2.05	4.00	5.59	9.9

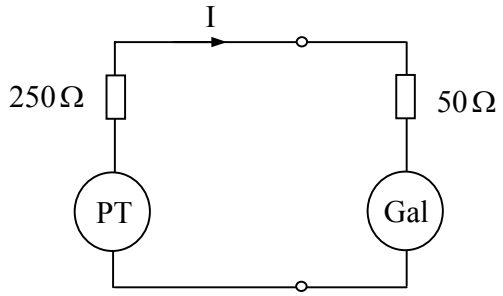
Draw calibration graph for the gauge under test, and determine the error in a reading (a) 5.0 bars, b) 9.0 bars as a percentage of full scale. Does the gauge meet its stated accuracy of $\pm$ 2.0% f.s.d (full scale deflection)?

4. A piezo-electric transducer of sensitivity 80.0 pC/bar is used to measure a mean pressure. The transducer signal is fed into a charge amplifier which has the sensitivity ranges of 0.05, 0.1, 0.2, 1.0, 2.0, 5.0, 20.0 and 100.0 mV/pC. The charge-amplifier signal is displayed on an oscilloscope whose sensitivity is set at 1.0 V/cm. If the pressure being measured is 21 bar, what charge-amplifier range would be required to obtain a trace deflection of approximately 80mm? What would the actual trace deflection be at this setting? [5 mV/pC; 84 mm]

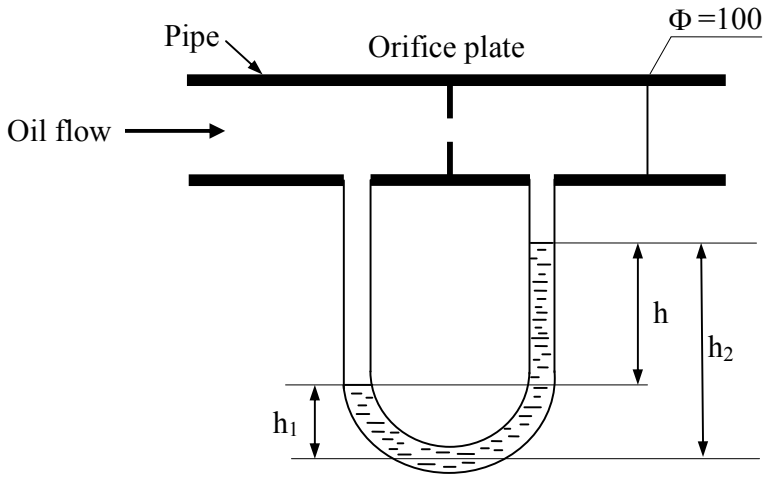
5. A pressure transducer has a sensitivity of 1.5 mV/bar and an output impedance of 200 Ω. If this is connected to a galvanometer of resistance 50 Ω having a sensitivity of 10 mm/ μA, calculate the pressure being measured if the galvanometer spot deflects 50 mm on the ultra-violet-sensitive paper. [0.83 bar]

6. A pressure transducer has a sensitivity of 2.5 mV/bar when correctly energised. The output impedance of the transducer is 250 Ω and it is connected to a galvanometer with an internal

resistance of 50 Ω (see the figure below). If the galvanometer has a sensitivity of 10 mm/μA and the galvanometer spot deflects 75 mm, determine the magnitude of the pressure being measured.

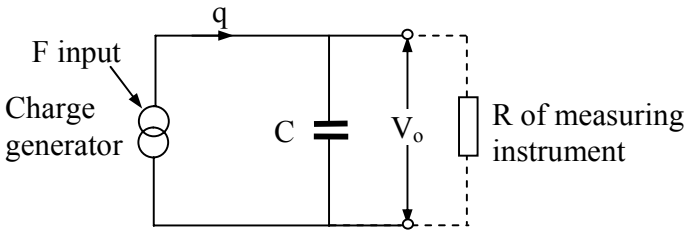


7. A U-tube mercury manometer and an orifice plate are applied in measurement of weight of oil flowing through a pipe in an offshore production system as shown in the following figure. The pipe has the internal diameter of 100 mm, and a constant K of 1.41. The difference in the mercury levels in the two legs is 60mm. The oil density is 850 kg/m^3, and mercury density is 13.56×10^3 kg/m^3.



Calculate:
(i) Differential pressure
(ii) Volumetric flow of oil in the pipe
(iii) Mass of the oil flowing through the pipe for one day

8. A piezo-electric pressure transducer (pressure-capacitance transducer) has a sensitivity of 80.0 pC/bar (see the following figure).



(a) If it has a capacitance of 1 nF, determine its output voltage (V_o) when the input pressure is 1.4 bar.
(b) If the range of input is 0.5 bar – 2.5 bar, determine the range of output voltage.
(c) If the resistance of measuring (R) is $10\,\Omega$, calculate the range of output current.

9. A tank holds water with a depth of 7.0 ft. What is the pressure at the tank bottom in psi and Pa (density = 10^3 kg/m^3). [p = 3 psi]

10. A pressure sensor that outputs 25 mV/kPa for a pressure variation of 0.0 to 25 kPa will be used to measure the level of a liquid with a density of 1.3×103 kg/m^3. What voltage output will be expected for level variations from 0 to 2.0 m? What is the sensitivity for level measurement expressed in mV/cm? [3.185 mV/cm]

11. Water is pumped through a 1.5-in diameter pipe with a flow velocity of 2.5 ft/s. Find the volume flow rate (ft^3/min) and weight flow rate (lb/min). The weight density is 62.4 lb/ft^3. [Q = 1/8 ft^3/min, F = 112 lb/min].

12. Flow is to be controlled from 20 to 150 gal/min. The flow is measured using an orifice plate system. The orifice place has a constant of 119.5 (gal/min)/psi$^{1/2}$. A bellows measures the pressure with an LVDT so that the output is 1.8 V/psi. Find the range of voltages that result from the given flow range. [min = 0.0504 V, max = 2.836 V].

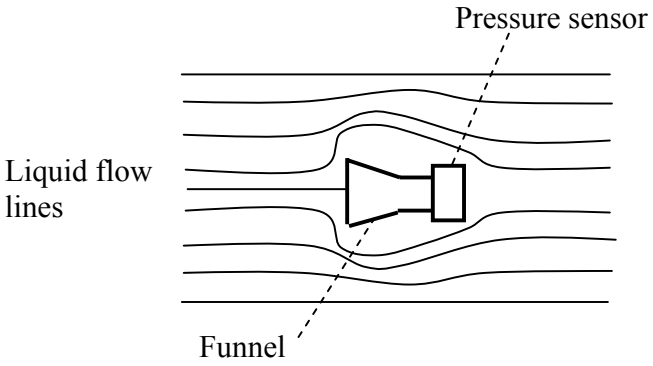
13. Calculate (a) the pressure in atmospheres that a water column 3.3 m high exerts on its base and (b) the pressure if the liquid is Mercury. Convert these results to Pascals. Mercury density is 13.546 kg/cm^3.

1.4 A welding tank holds oxygen at 1500 psi. What is the tank pressure expressed in Pa? What is the pressure in atmospheres?

15. A diaphragm has an effective area of 25 cm^2. If the pressure difference across the diaphragm is 5 psi, what force is exerted on the diaphragm?

16. The following figure shows a proposed sensor for measuring the speed of liquid flowing in an open channel. A pressure sensor is connected to a funnel as shown. A pressure is formed when the funnel has its open end pointed upstream so that the liquid is brought to rest against the funnel opening. The pressure is given by $p = \frac{1}{2}\rho v^2$, where ρ is the liquid density in kg/m^3 and v is the liquid speed in m/s. The pressure sensor has a range of 0 to 5 kPa with a transfer function of 40 mV/kPa. Suppose the liquid is water with a density of 1.0 g/cm^3. What is the maximum speed

which can be measured? Plot a graph of sensor output voltage versus liquid speed. Comment of the linearity.



17. The bellows, diaphragm, and Bourdon tube pressure sensors all exhibit second-order time response. This means that a sudden change in pressure will cause an oscillation in the displacement and, therefore, in sensor output. Because they are like springs, they have an effective spring constant and mass, so the frequency can be estimated by

$$f_m = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Consider a bellows with an effective spring constant of 3500 N/m, and mass of 50 g. The effective area against which the pressure acts is 0.5 in^2. Calculate (a) the bellow defection for a pressure of 20 psi and (b) the nature frequency of oscillation.