Week 8 Assignment on Pressure and low-pressure Measurements

1) A well-type manometer, shown in Figure 1, is used to measure differential air pressure ($P_1 - F$). The manometric liquid has density ($\rho_m$) of 1000 kg/m$^3$. The ratio of well diameter ($a_w$) to tube diameter ($a_t$) is 10. If a scale of simple U-tube manometer is used for this system, then find the magnitude of percentage error in measurement. (Assume density of the fluid over manometer fluid $\ll \rho_m$)

(In well-type manometer, change in liquid height ('h', as in Figure 1) due to pressure difference in the tube is only measured. That will be the source of error.)

![Figure 1](image)

(Hint: For a U-tube manometer, $P_1 - P_2 = h\rho_m g$. Find out the expression of $(P_1 - P_2)$ for well-type manometer based on $a_w$ and $a_t$. Then find the error.)

- a) 0.1 %
- b) 1 %
- c) 10 %
- d) None of these

Accepted Answers:

b) 1 %

2) The tube of the above well-type manometer is inclined at an angle 30° with vertical axis. Find out the percentage change (increase or decrease) in 'h' (length of liquid in the tube) compare to a well-type manometer for measuring same differential pressure.
A pressure gauge is designed using a diaphragm and LVDT arrangement. The LVDT core is connected to the centre point of deflection of the diaphragm. The diaphragm has the following characteristics: Poisson’s ratio (\(\nu\)) 0.25, density of diaphragm material 7000 kg/m\(^3\), Modulus of elasticity for the diaphragm material \((E) = 2 \times 10^{11}\) Pa, radius of diaphragm (R) 10 cm. Calculate diaphragm thickness ‘t’ such that non-linearity is 1%. Assume, maximum pressure is 1 MPa.

Accepted Answers:
c) 15.5 %  

3) 

In problem 3, calculate the resolution of the system, if the LVDT has sensitivity of 0.5 V/mm and the output is measured using a millivoltmeter, capable of measuring minimum of 0.1 mV.

Accepted Answers:
c) 4.97 mm  

4) 

In the Figure 2, four strain gauges are placed over a diaphragm. The diaphragm has the following specifications:

- \(r_t = 0.02\) m, \(r_f = 0.08\) m, \(D = 0.2\) m, Poisson’s ratio \(\nu = 0.3\), \(E_{ref} = 10\) V, Gauge resistance = 100 \(\Omega\), Gauge factor (\(\lambda\)) 2, diaphragm density = 7000 kg/m\(^3\), Modulus of elasticity for the diaphragm material = \(2 \times 10^{11}\) Pa, sensitivity = \(10^{-4}\) mV/Pa.

Find diaphragm thickness ‘t’.

(Hint: (i) Evaluate expression for radial stress \(\sigma_r\) and tangential stress \(\sigma_t\) for both \(r_r\) and \(r_t\). (ii) Evaluate expression for radial strain \(e_r\) and tangential strain \(e_t\). (iii) Evaluate expression for resistances of four strain gauges. (iv) Finally calculate ‘t’ from output voltage \(e_o\) of Wheatstone bridge, if four strain gauges are connected in the bridge.)

Accepted Answers:
d) 281.8 N/m\(^2\)
6) A McLeod gauge has a bulb of volume 100 cm³. The diameter of the capillary is 1 mm. Calculate the gauge pressure indicated by the capillary tube when a pressure of 100 μm of Hg is applied.

- a) 0.08 m
- b) 0.113 m
- c) 0.183 m
- d) None of these

**Accepted Answers:**
- b) 0.113 m

7) For an ionization gauge, pressure of the gas in the vessel is $10^{-11}$ torr and sensitivity is 50/torr. 0.01 μA ion current is generated in the vessel, calculate the electron current.

- a) 20 A
- b) 20 mA
- c) 2 A
- d) 200 mA

**Accepted Answers:**
- a) 20 A

8) The following bridge circuit is used for measurement of low pressure by Pirani gauge. Resistance of the filament (R₁) changes with applied pressure, following the relation, $R₁ = R₀×(1-k×P)$, where k is a sensitivity constant, P is applied pressure, $R₀$ is nominal resistance under no pressure. (Null-deflection measurement done using deflection-galvanometer 'D')

Assume range of P is $10^{-3}$ to 1 torr. Find (i) maximum value of k, if allowable nonlinearity in R-P relation is 1%. Also find (ii) value of $R'$ for measuring maximum pressure, using the above value of k (Assume, $R₀ = 1$ kΩ).

![Diagram](https://onlinecourses.nptel.ac.in/noc17_ec09/unit?unit=35&assessment=89)

- a) (i) 0.02/Torr; (ii) 485 Ω
- b) (i) 0.01/Torr; (ii) 4850 Ω
- c) (i) 0.01/Torr; (ii) 485 Ω
- d) None of these

**Accepted Answers:**
- a) (i) 0.02/Torr; (ii) 485 Ω
Accepted Answers:

a) (i) 0.02/Torr; (ii) 485 Ω