Q1) A venturi meter of unknown diameter is used to measure the flow rate of water (density of water = 1000 kg/m³ and dynamic viscosity = 1.08×10^{-3} N-s/m²) inside a horizontal pipe of 100mm. The venture has coefficient of discharge = 0.99. The pressure drop between the throat and inlet was measured using two pressure gauges. The differential pressure shown by those gauges was equal to 355.6 kPa. The pressure loss in the system caused by this venturimeter is 75% of the pressure drop.

(7 Marks)

5

✓ **Answer the following:**

The accuracy of Obstruction Flow Measurement Devices depends on (State two):

1. density of flow
2. diameter

The scientific name for the flow measurement calibration devices is .... and the main scientific principle it is based on is ....Catch and wieght....................

The main selection criteria for Obstruction Flow Measurement Devices (other than cost and accuracy) are (state two) :

1. available distance
2. Nature of flow.

How much was the value of the venturi throat diameter (d_2) such that the actual flow rate measured was 0.08 m³/s.

actual volumetric flow rate $(\dot{Q}) = \frac{C_D \times \pi \times d_2^2}{4\sqrt{1-\left(\frac{d_2}{0.1}\right)^4}} * \sqrt{2 \times g \times \frac{\Delta P}{\gamma_f}}$

$0.08 = \frac{0.99 \times \pi \, d_2^2}{4\sqrt{1-\left(\frac{d_2}{0.1}\right)^4}} * \sqrt{2 \times 9.81 \times \frac{355.6 \times 10^3}{9810}} \Rightarrow d_2 = 60 \text{ mm}.$ By solving

If the pressure gauges were replaced with mercury manometer (SGm = 13.6) how much will be the deflection indicated by the manometer.

pressure drop $\frac{P_1 - P_2}{\gamma_f} = h_m\left(\frac{\rho_m}{\rho_f} - 1\right)$

$\frac{355.6 \times 10^3}{9810} = h_m\left(\frac{13600}{1000} - 1\right) \Rightarrow h_m = 2.876 \text{ m Hg}.$

If the compensating pump used is designed to run for 6500 hr/yr with electricity tariff rate of 0.0775 JD/kw-hr, how much should be the efficiency of the pump such that the cost of using this pump does not exceed 12000 JD/yr.

cost = $\dot{W}_p$ × Tarriff rate × time

$12000 \frac{JD}{yr} = \dot{W}_p \times 0.0775 \frac{JD}{kW \cdot hr} \times 6500 \frac{hr}{yr}$

$\Rightarrow \dot{W}_p = 23.821$ kW

Now

pump power $(\dot{W}_p) = \frac{\dot{Q}\,\Delta P_{loss}}{\eta_p}$

$23.821 \times 10^3 = \frac{0.08 \times 0.75 \times 355.6 \times 10^3}{\eta_p}$

$\Rightarrow \eta_p = 89.57\%$

?! If the relative uncertainty in the volumetric flow rate is not to exceed ±3.5%. With uncertainty in the flow coefficient = 0.015, throat area = ±1.5% and the value of coefficient of discharge as ±1.25%. How much should be the uncertainty of the pressure gauges to achieve these conditions.

$$\dot{Q} = \frac{C_D A_2}{\sqrt{1-\beta^4}} \sqrt{2g \frac{\Delta P}{\gamma_f}} \Rightarrow \dot{Q} = M C_D \frac{\pi}{4} D_2^2 \sqrt{2}^{0.5} \times \sqrt{\Delta P} \times \gamma_f^{-0.5}$$

$$\sqrt{\Delta P} = \dot{Q} M^{-1} C_D^{-1} \frac{\pi}{4}^{-1} D_2^{-2} \times 2^{-0.5} \times \gamma^{0.5}$$

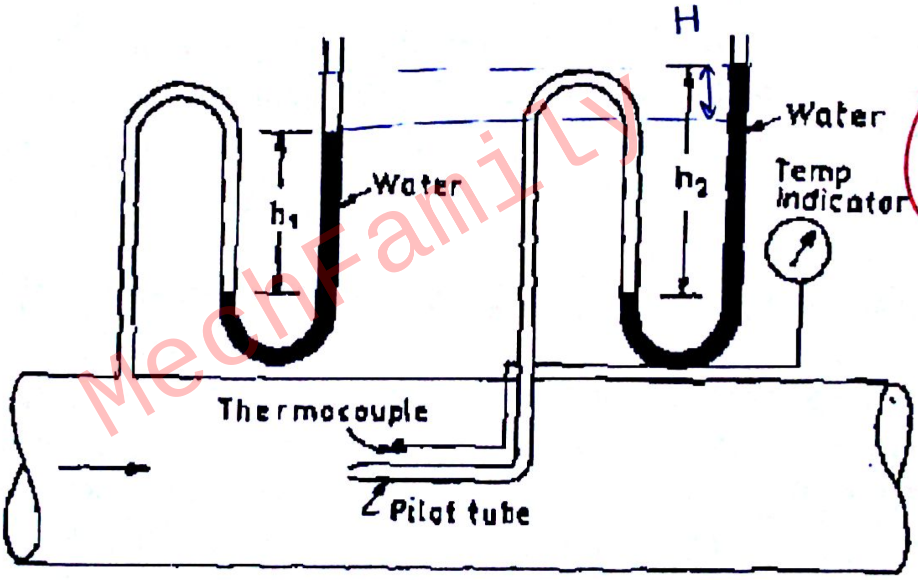
$$\Delta P = \dot{Q}^2 M^{-2} C_D^{-2} A_2^{-2}$$

$$\frac{W_{\Delta P}}{\Delta P} = \sqrt{\left(2\times\frac{3.5}{100}\right)^2 + \left(\frac{0.015}{1.0718}\times 2\right)^2 + \left(2\times\frac{1.25}{100}\right)^2 + \left(2\times\frac{1.5}{100}\right)^2}$$

$\frac{W_{\Delta P}}{\Delta P} = \pm 2.50$ ~~(8)~~ % ~~Howll~~

Q2) The static head, the velocity and temperature of air flowing in duct is measured by piezometer, pitot tube and a temperature probe respectively as shown in Figure below.

The temperature is 20°C and the readings of manometer; are h1 = 50 mm, and h2 = 80 mm of water. The barometer reads 760 mm of mercury. Take gas constant R =287 J/kg_K, The specific gravity of mercury is 13.6. **(2 Marks)**



✓ Answer the following:

The factors affecting the accuracy of Pitot tube are (State two):

1. Flow should be clean & straight
2. Nature of flow

?! For this Pitot tube, calculate the value of the stagnation pressure and flow velocity of the air.

Fluid manometer hight $\Delta h_m = 10$ cm H_2O

$\frac{P_s - P_1}{\gamma} = H$

$P_s = \gamma H + P_1$
$= \rho g H + P_1$
$= 1.201 \times 9.81 \times 0.1 + 101$

$P_s = 102.18$ kPa

velocity of flow (U_f)

$U_f = \sqrt{2 g h_m}$
$= 1.4$ m/s

Ideal gas Law

$P V = m R T$

$P = \rho R T$

$\frac{101}{0.287 \times 293} = \rho$

$\rho_a = 1.201 \frac{kg}{m^3}$

Q3) A flat circular diaphragm used as a transducer for pressure measurement. It is made of mild steel having the following properties: Modulus of elasticity = 210±0.2% GN/m², Poisson's Ratio = 0.28, Density = 160x10³ ±0.35% kg/m³ and the diameter of the diaphragm is 15.0±0.15cm. **(4 Marks)**

4

✓ **Answer the following:**

What is the most critical criteria for the design and use of diaphragm as pressure measurement device using the equations supplied to you? Why?

most critical criteria is: ~~The~~ max Deflection $\le \frac{1}{2}$ thickness to keep the relation is linear.

What thickness should it have if the maximum stress (σ) is not to exceed 375 ±2% MN/m² under pressure of 335 ±1.25% KPa.

maximum stress $(\sigma_m) = \frac{3D^2P}{16t^2} \Rightarrow 375\times10^6 = \frac{3\times(15\times10^{-2})^2\times335\times10^3}{16\times(t^2)}$

$\Rightarrow t^2 = 1.941$ mm.

Using the thickness value of part (1), how much will be the value of the maximum deflection at the center (assuming UDL). Comment on your result.

pressure Applied $(P) = \frac{256\,E\times t^3\times\delta m}{3(1-\nu^2)D^4} \Rightarrow 335\times10^3 = \frac{256\times210\times10^9\times(1.941\times10^{-3})^3\times\delta m}{3(1-0.28^2)(15\times10^{-2})^4}$

$\Rightarrow \delta m = 1.193$ mm

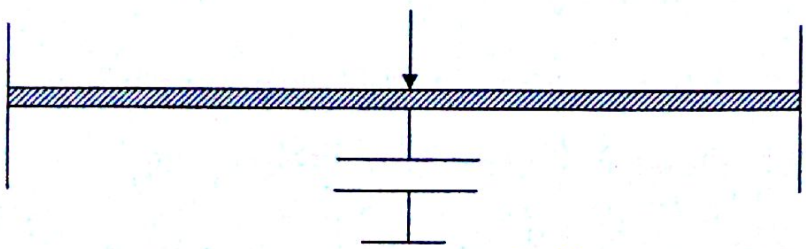
→ this Design is not Valid Because $\delta m \not< \frac{1}{2}t$, so, we should increase thickness OR Decrease diameter.

A capacitive transducer is connected at the center of this diaphragm from its bottom (opposite to face under load) having the following parameters: area = 750 mm2, separated by distance of 3.5mm and free load capacitance is 370 pF. How much will be the final capacitance if subjected to conditions shown below.

Before ⇒ Capacitance $(C) = \epsilon_0\epsilon_r\times\frac{A}{d} \Rightarrow 370\times10^{-12} = \epsilon_0\epsilon_r\times\frac{750\times10^{-6}}{3.5\times10^{-3}}$

$\therefore \epsilon_0\epsilon_r$ (permitivity) $= 1.727\times10^{-9}\ \frac{F}{m}$

$\delta = 1.193$ mm



→ after :- $d = 3.5\text{ mm} - 1.193\text{ mm} = 2.307$ mm

$\therefore C_f = \epsilon_0\epsilon_r\times\frac{A}{d} = 1.727\times10^{-9}\times\frac{750\times10^{-6}}{2.307\times10^{-3}} = 561.44$ PF

(final capacitance)

Q4) The following table shows the variation of the resistance of a sensor with the change in its temperature. The device is been calibrated at 0 ºC. **(5 Marks)**

To

T (°C)	-30	-10	0	10	30	40	60	80	90	100	110
R (Ω)	239.58	292.3	423.58	624.82	1237.1	1648.2	2680.2	3992	4752.8	5583.6	6484.3

This device was used for temperature measurement at certain temperature and gave resistance value = 3848.242 Ohm.

RTD ← R↑ ↔ T↑

✓ **Answer the following :**

What are the qualities of materials used for this device (State two).

1. have linear R-T Relation in this Range
2. corrosive Resistance. & Non-Toxic.

Derive the best and most accurate mathematical law it follows for the whole range the range around the calibrated point? State why you have chosen this equation?

How much was the temperature measured by this device. [Use the most correct formula].

What will be the reading of this instrument at T=120 C?

Q5) A potentiometer resistance has resistance = 5000 Ohm (R_p) and rated power of 3 kW. **(4 Marks)**

What is the maximum allowable supplied voltage so that the power rating is not exceeded?

(maximum input voltage) $(V_{i,max}) = \sqrt{P \times R_p}$ $\quad w = \frac{V^2}{R} = RI^2$

$= \sqrt{5000 \times 3 \times 10^3}$

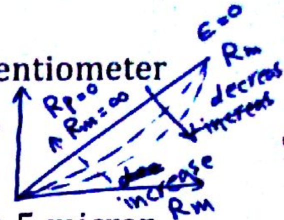
$= 3872.98$ Volt

$R = \frac{\rho L}{A}$

State two solutions (new designs) to the power rating problem in potentiometer.

1. Reduce length of wire (R_p), to reduce Heat rating (reduce resistance)
2. increase cross section of wire.

As the value of Rm increases, the non-linearity in measurement using potentiometer decrease. Draw proper graph supporting your answer. Use proper format.



Q6) A compressive force is applied to a structural member. The strain is -5 micron. Two separate strain gauges are attached to the structural member. One strain gauge is made of Nickle (unstrained resistance = 120Ω, gauge factor = -12.1), the other one is made of Nichrome (unstrained Resistance = 120Ω, gauge factor = 2).

(4 Marks)

3

What are the main types of a strain gauge?

1. Bonded wire 2. Bonded foil 3.

State THREE main configurations used for strain gauge?

1.  2.

For Q6, calculate the resistance of each one after they are strained.

Nickel: G_f (Gauge factor) $= \frac{\Delta R / R}{\epsilon} \Rightarrow -12.1 = \frac{\Delta R/R}{-5 \times 10^{-6}} \Rightarrow \frac{\Delta R}{R} = 6.05 \times 10^{-5} \Rightarrow \Delta R = +7.26 \times 10^{-3}\ \Omega$

$R_f = 120.00726\ \Omega$

Nichrome: Gauge factor $(G_f) = \frac{\Delta R/R}{\epsilon} \Rightarrow 2 = \frac{\Delta R/R}{-5 \times 10^{-6}} \Rightarrow \Delta R = -1.2 \times 10^{-3}\ \Omega$

$R_f = 119.9988\ \Omega$

Q7) A thermistor has resistance of 8632.371 Ohm at 10 °C and 101.17 Ohm at 140 °C. The calibrated resistance (reference resistance) is equal to 3987.1258 Ohm. The Resistance-Temperature relationship is given by the logarithmic approximation.

4 **(4 Marks)**

State two main differences between Thermistor and an RTD?

1. Thermistor used for low Temperature But RTD for high tempreture
2. In thermisto "R" (Resistance) decrease when "T" (Temperature) increase But RTD "R" (Resistance) increase when Tempreture increase

What will be its resistance at 80 °C. Show the calculation steps. Comment on your results. let $T_1 = 10 C°$, $R_{T_1} = 8632.371\ \Omega$, $T_2 = 140\ C°$, $R_{T_2} = 101.17\ \Omega$, $T_1 = 283\ K$, $T_2 = 413\ K$

Resistance at T_2 / Resistance at T_1: $\frac{R_{T_2}}{R_{T_1}} = e^{B\left(\frac{1}{T_2} - \frac{1}{T_1}\right)} \Rightarrow \frac{101.17}{8632.371} = e^{B\left(\frac{1}{413} - \frac{1}{283}\right)} \Rightarrow B = 3997.686\ K$

Draw the characteristic curve for this device using proper graph format. (Next page)

Resistance at T_1: $R_{T_1} = a R_{T_0} \exp\left(\frac{b}{T_1}\right)$

$8632.371 = a \times 3987.1258\ e^{\frac{3997.686}{283}} \Rightarrow a = 1.587 \times 10^{-6}$

Now $R_T = a R_{T_0} \exp\left(\frac{b}{T}\right)$

$R_T = 1.587 \times 10^{-6} \times (3987.1258)\ e^{\frac{3997.686}{353}} \Rightarrow R_{T=80} = 524.29\ \Omega$