MECH 373/2 : Instrumentation and Measurements

ASSIGNMENT #1

#1 (a) desired or ideal output, $y_d = (K)(\text{input})$

$= 2.5 \frac{mV}{psig} * 100 \text{ psi}$

$y_d = 250 \text{ mV}$

output due to interfering inputs (thermal zero drift):

$$y_I = \left(\frac{\text{output due to thermal zero drift}}{}\right) * \Delta T$$

$$= \frac{0.015}{100} * \text{F.S.} * \Delta T = \frac{.015}{100} * 5000 * (100 - 70)$$

$y_I = 22.5 \text{ mV}$

output due to modifying or sensitivity drift:

$$y_m = \left(\frac{\text{output due to sensitivity drift}}{}\right) * \Delta T$$

$$= \left(\frac{0.01}{100} * K * \text{input}\right) * \Delta T$$

$$= \left(\frac{.01}{100} * \frac{2.5 \text{ mV}}{\text{psig}} * 100 \text{ psi}\right) * (100 - 70) = 0.75 \text{ mV}$$

$y_L = \frac{.3}{100} * 5000 = 15 \text{ mV}$

output due to hysteresis: y_H

$y_H = \frac{0.15}{100} * \text{FSO} = 7.5 \text{ mV}$

(output span = full-scale-operating range $= X_{max} - X_{min}$)

Total output: $y = y_L + y_d + y_I + y_m + y_H = 295.75 \text{ mV}$

295.75 mV.

b) Absolute value of Linearity error:

@ 100 psig input $= \pm \frac{0.3}{100} * 5000 = 15 \text{ mV}$

The linearity error is same for 600 psig.

(b) - Cont'd Hysteresis at 100 psig = y_H in part (a)

y_{H100} = 7.5 mV ✓

@ 6000psig, $y_{H6000} = \frac{0.25}{100} * 5000 =$ 12.5 mV ✓

#2

a) % Hysteresis : Identify the peak difference between uploading and downloading readings ($V_o\uparrow$, $V_o\downarrow$)

h	0	1.5	3	4.5	6	7.5	9	10.5	12	13	15
$\varepsilon = V_o\uparrow - V_o\downarrow$	-.14	-0.9	-0.9	-1.15	-1.0	-1.35	-1.17	-1.3	-1.3	-1.1	0.

✓ peak error = 1.35 V at h = 7.5 cm FSO = 10.2V

% Hysteresis = $\frac{\text{peak error}}{FSO} * 100 = \frac{1.35}{10.2} * 100 = 13.235\%$

b) Sensitivity and zero-drift

Sensitivity is derived as the slope of the best fit line. The slope of the best fit line can be derived from: $Y = MX + C$ plot or ↓

✓ $m = \frac{N\sum x_i y_i - \sum x_i \sum y_i}{N\sum x_i^2 - (\sum x_i)^2}$; ✓ x_i = input value, h (cm)

✓ y_i = output value, $V_o\uparrow$, $V_o\downarrow$

✓ N = 22 readings

✓ $\sum x_i = 2[0 + 1.5 + 3 + 4.5 + 6 + 7.5 + 9 + 10.5 + 12 + 13.5 + 15] = 165$

✓ $\sum x_i^2 = 1732.5$ ✓ $\sum y_i = 111.57$ ✓ $\sum y_i^2 = 809.3735$

✓ $\sum x_i y_i = 1180.02$

The slope m, is computed as ✓ m = 0.693

✓ Similarly, the intercept C is derived from

$$C = \frac{\sum x_i^2 \sum y_i - \sum x_i \sum x_i y_i}{N \sum x_i^2 - (\sum x_i)^2} = -0.129$$

The readings can thus be expressed by the best fit line

$$V_o = mh + C = 0.693h - 0.129$$

$\therefore$ $K = 0.693$ V/cm ; Zero-shift $= -0.129$ V.

#3 Problem 1.9 from text

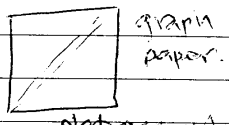
From Table 1.5: Input range: $0.5 \le x_i \le 100$ cm

Output range: $0.4 < y_i < 253.2$ V

Input span $x_i = x_{max} - x_{min}$ output span (FSO) $[V_o] = y_{max} - y_{min}$.

$\therefore$ $x_i = 99.5$ cm and $y_o = 252.8$ V

#4 Problem 1.12 from text



Hysteresis error: $(e_H)_{max}$, where

$e_H = y_{up} - y_{down}$

From Table 1.6, $(e_H)_{max} = 0.2$ mV at $x = 3$.

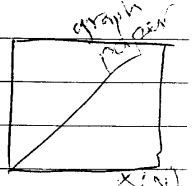
$$\% (e_H)_{max} = \frac{e_{H\,max}}{FSO} \times 100\% = \frac{.2}{5} \times 100 = 4\%$$

#5 Problem 1.16 from Text

The data may be plotted or a best-fit analysis may be carried as outlined in problem #2. The best fit line of the form:

$$y = 1.365x + 2.12$$

$\therefore$ $K = 1.365$ for all values of x.



6 Problem 1.22 in the text

FSO: $R_i = 1000\ N$

Linearity error: $e_L = \frac{0.1}{100} * R_i = 1\ N$

Hysteresis error: $e_H = \frac{.1}{100} * R_i = 1\ N$

Repeatability error: $e_R = \frac{.15}{100} * R_i = 1.5\ N$

Zero drift err $e_Z = \frac{.2}{100} * R_i = 2\ N$

overall error:

$$e_I = \sqrt{e_L^2 + e_H^2 + e_R^2 + e_Z^2} = 2.87\ N$$

7 Problem 1.32 in the text

$$Q = CA\sqrt{\frac{2\,dp}{\rho}}$$

$D = 1\ m$

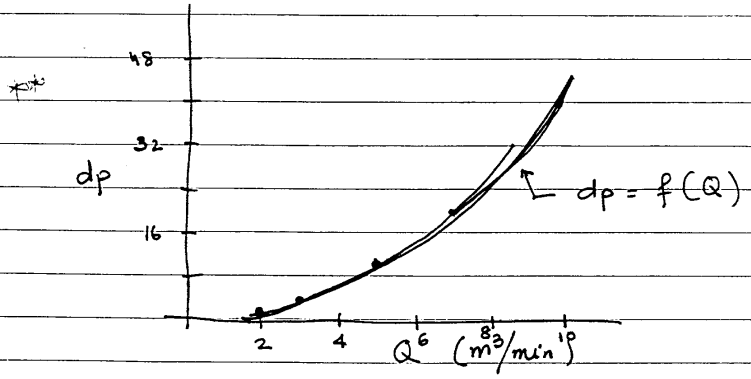
$C = 0.75$

$\rho = 998\ kg/m^3$

$A = \frac{\pi D^2}{4} = 0.7854\ m^2$

Q m^3/min	2	5	10	3	7
dp N/m^2	1.6	10	40	3.595	19.57

* $dp = \frac{\rho}{2}\left(\frac{Q}{CA}\right)^2$



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* $K = f(Q) \neq Const$