Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

COURSE NAME	:	INDUSTRIAL SENSOR SYSTEMS
COURSE CODE	:	BND 30503
PROGRAMME CODE	:	BND
EXAMINATION DATE	:	DECEMBER 2016 / JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

Q1 (a) The purpose of a measurement system is to link the observer to the process. The observer is presented with a number or reading which is the current value of the information variable. Define the following terms in measurement system:

(i) Reference value
(ii) Resolution
(iii) Precision
(iv) Accuracy

(4 marks)

(b) A perfectly accurate system is theoretically ideal and the accuracy of a real system is quantified using measurement system error, *E*. Determine the system error *E* if:

(i) the measured value of rotational speed of an engine is 6830 rpm and the true value is 6540 rpm

(3 marks)

(ii) the measured value of flow rate of gas in a pipe is 17.1 m^3/h and the true value is 18.3 m^3/h

(3 marks)

(c) Describe the purpose of calibration for a measuring instrument. Suppose an instrument is labelled as "calibrated". Differentiate the performance of a calibrated instrument over uncalibrated instrument.

(5 marks)

(d) A type-J thermocouple circuit shown in **Figure Q1(c)** is used to measure the temperature T_1. The thermocouple reference junction labeled 2 is maintained at a temperature of 30°C. The voltage output is measured using a potentiometer and found to be 6.857 mV. Thermocouple table is provided in **Table Q1(c)**. Given that

$$emf_{(T_h,T_0)} = emf_{(T_h,T_r)} + emf_{(T_r,T_0)}$$

$$T_x = T_a + \frac{(emf_x - emf_a)}{(emf_b - emf_a)} \times (T_b - T_a)$$

(for interpolation, use notation T_a and T_b for lower and upper temperatures)

(i) Determine the sensed temperature at the measuring junction, T_1.

(6 marks)

(ii) Supposed the measurement is taken another two times with the same measuring environment (no temperature change), but the voltage output obtained is 6.938 mV and 6.736 mV. Calculate the uncertainty of the thermocouple in terms of its potentiometer reading. The standard uncertainty calculation is given by

$$b_{\bar{Q}} = \frac{s_{\langle Q \rangle}}{\sqrt{m}} = \frac{\sqrt{\sum_{j=1}^{m} \frac{(Q_j - \langle Q \rangle)^2}{2}}}{\sqrt{m}}$$

(4 marks)

Q2 (a) Thermography (thermal imaging) and radiation pyrometer are two instruments that use the concept of collecting radiation data and convert them to temperature measurement.

(i) Explain the difference between thermography (thermal imaging) and radiation pyrometer.

(3 marks)

(ii) Give **FIVE (5)** examples of thermography application.

(5 marks)

(b) Convert the following pressure measurements, with the absolute pressure reference scale given as:

1 atm abs = 14.69 psia = 101.325 kPa abs = 101,325 N/m² abs

1 atm abs = 760 mm Hg abs = 406 in H_2O abs

1 bar = 100,000 N/m²

$$P_{abs} = P_{gauge} + P_0$$

(i) Absolute pressures to gauge pressure units of *kPa*

- 17.25 psia
- 10.63 bars abs

(4 marks)

(ii) Gauge pressures into absolute pressure relative to 1 bar

- -9.76 psia
- -95 mm Hg

(4 marks)

(c) Manometers are well-known pressure reference instruments that provide precise measurement of pressure. Describe the difference between U-tube manometer, well-type manometer, and inclined manometer. Include illustration to support your answers.

(6 marks)

(d) A user wants to use a Bourdon tube-type sensor to measure high pressure reading (up to 6000 bar). Illustrate and suggest the type of Bourdon tube suitable for his measurement requirement together with its advantages.

(3 marks)

Q3 (a) State **FOUR (4)** basic requirements for a good and reliable flow measurement.

(4 marks)

(b) A conveyor-based mass flow sensor at a mine site shown in **Figure Q3(b)** is usually used for measuring the flow of solids in the form of powders or small granular particles. The conveyor-based mass flow sensor measures the mass of 27 kg, of crushed stones distributed over a conveyor length of 2 m. If the conveyor velocity is 2.5 m/s, calculate the mass flow rate, $\dot{m}$. Given that

$$\dot{m} = \frac{M}{L}.v$$

(4 marks)

(c) Flow nozzle as depicted in **Figure Q3(c)** consists of a gradual contraction from the pipe's inside diameter down to a narrow throat. Ideal mass flow rate for a perfect gas is given by

$$\dot{m} = \rho_1 A_0 \sqrt{2RT_1} \sqrt{\frac{k}{k+1}\left(\frac{2}{k+1}\right)^{2/(k-1)}}$$

where

ρ_1 = pipe pressure (kPa)

A_0 = nozzle throat area (m^2) = $\pi d_0^2/4$

d_0 = nozzle throat diameter (m)

R = ideal gas constant ($N.m/kg.K$)

T_1 = temperature (K)

k = specific heat ratio of the gas

(i) A flow nozzle is designed with β nozzle ratio of 0.743 through a 10 cm-i.d. pipe to regulate the flow of Ethane C_2H_6. The pipe is pressurized at 700 kPa abs and gas flows at 20°C. Determine the mass flow rate of the gas. ($R_{C_2H_6}$ = 276 $N.m/kg.K$ and $C_2H_6(k = 1.187)$). Given that $\beta = d_0/d_1$.

(5 marks)

(ii) A flow nozzle is to be used at choked conditions to regulate the flow of Nitrogen N_2 at 1.3 kg/s through a 6 cm-i.d. pipe. The pipe is pressurized at 690 kPa abs and gas flows at 20°C. Determine the maximum β nozzle ratio that can be used. ($R_{N_2} = 297\ N.m/kg.K$ and $N_2(k = 1.4)$). Given that $\beta = d_0/d_1$.

(8 marks)

(d) Suggest **ONE (1)** type of flow meters that can be used if a food industry wanted to measure the flow of milk and juice without puncturing the pipe to avoid any contamination to the measured fluid. Describe the suitability by explaining the sensor operations.

(4 marks)

Q4 (a) Describe mass, force, weight and torque.

(4 marks)

(b) A strain gauge, having a gauge factor of 2, is mounted on a rectangular steel bar (E_m = 200 x 10^6 kN/m^2), is shown in **Figure Q4(b)**. The bar is 2 cm wide and 2 cm high, and is subjected to a tensile force, F_N of 40 kN. Determine the resistance change of the strain gauge, δR if the resistance of the gauge, R was 120 Ω in the absence of the axial load. Given that

- $\sigma_a = F_N/A_C = E_m\,\varepsilon_a$
- $\delta R/R = \varepsilon_a GF$

(8 marks)

(c) A pipe carrying a fluid vibrates at a frequency of 100 Hz with displacements of 25 mm from the equilibrium position.

(i) Calculate the peak acceleration, $\alpha_{peak} = \omega^2 X_0$

(3 marks)

(ii) Express the peak acceleration in terms of gravity, where g = 9.81 m/s^2

(2 marks)

(d) (i) An object is dropped from a height of 80 m and suffers a shock when it hits the ground. If the duration of the shock is 7 ms, calculate the magnitude of the shock in terms of g, where g = 9.81 m/s^2.

(4 marks)

(ii) Give **FOUR (4)** examples of shock measurement application.

(4 marks)

-END OF QUESTIONS -

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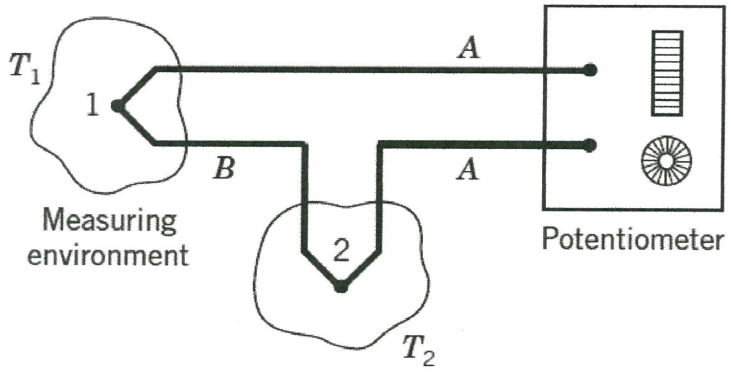

Figure Q1(c)

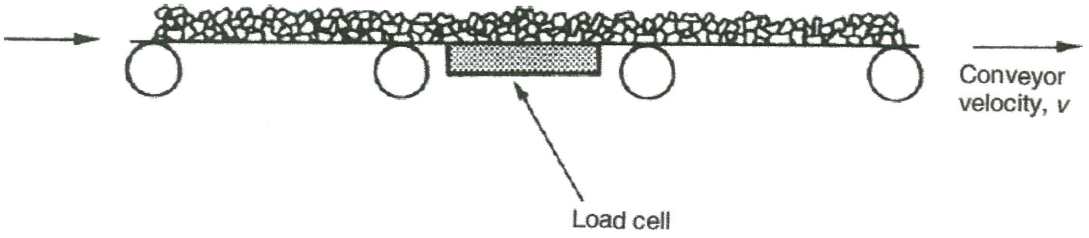

Figure Q3(b)

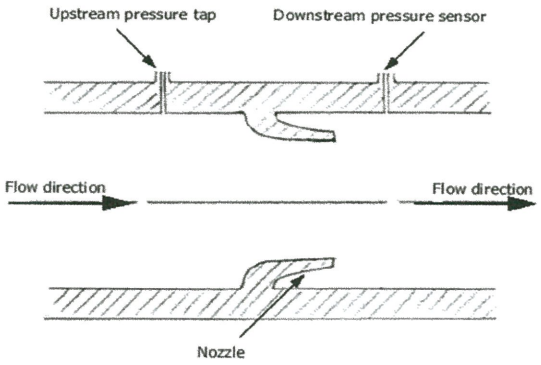

Figure Q3(c)

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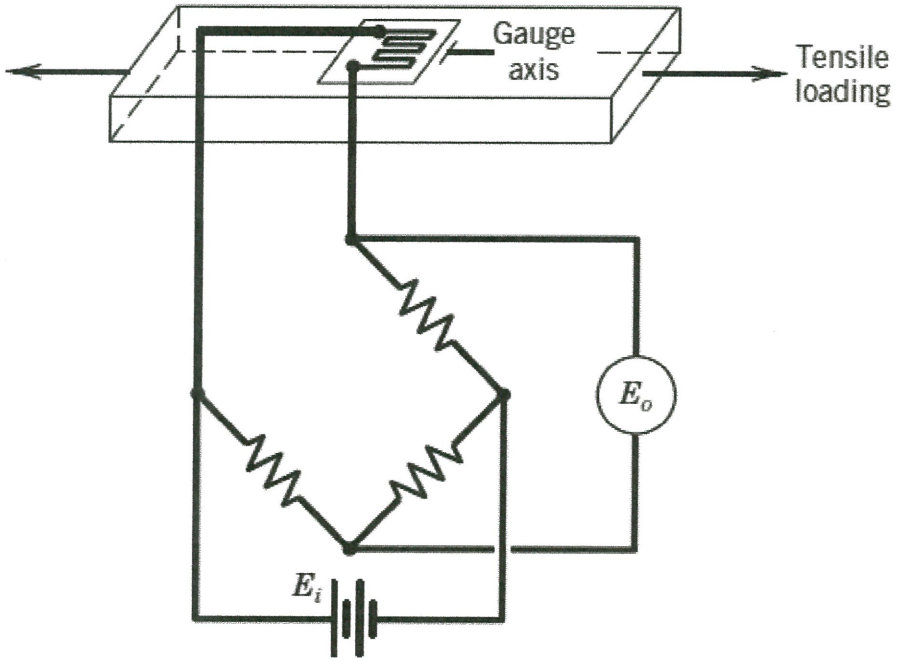

Figure Q4(b)

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Table Q1(c)

Temp. (°C)	Type E	Type J	Type K	Type N	Type S	Type T
0	0.000	0.000	0.000	0.000	0.000	0.000
10	0.591	0.507	0.397	0.261	0.055	0.391
20	1.192	1.019	0.798	0.525	0.113	0.789
30	1.801	1.536	1.203	0.793	0.173	1.196
40	2.419	2.058	1.611	1.064	0.235	1.611
50	3.047	2.585	2.022	1.339	0.299	2.035
60	3.683	3.115	2.436	1.619	0.365	2.467
70	4.329	3.649	2.850	1.902	0.432	2.908
80	4.983	4.186	3.266	2.188	0.502	3.357
90	5.646	4.725	3.681	2.479	0.573	3.813
100	6.317	5.268	4.095	2.774	0.645	4.277
110	6.996	5.812	4.508	3.072	0.719	4.749
120	7.683	6.359	4.919	3.374	0.795	5.227
130	8.377	6.907	5.327	3.679	0.872	5.712
140	9.078	7.457	5.733	3.988	0.950	6.204
150	9.787	8.008	6.137	4.301	1.029	6.702
160	10.501	8.560	6.539	4.617	1.109	7.207
170	11.222	9.113	6.939	4.936	1.190	7.718
180	11.949	9.667	7.338	5.258	1.273	8.235
190	12.681	10.222	7.737	5.584	1.356	8.757
200	13.419	10.777	8.137	5.912	1.440	9.286
210	14.161	11.332	8.537	6.243	1.525	9.820
220	14.909	11.887	8.938	6.577	1.611	10.360
230	15.661	12.442	9.341	6.914	1.698	10.905
240	16.417	12.998	9.745	7.254	1.785	11.456
250	17.178	13.553	10.151	7.596	1.873	12.011
260	17.942	14.108	10.560	7.940	1.962	12.572
270	18.710	14.663	10.969	8.287	2.051	13.137
280	19.481	15.217	11.381	8.636	2.141	13.707
290	20.256	15.771	11.793	8.987	2.232	14.281
300	21.033	16.325	12.207	9.340	2.323	14.860
310	21.814	16.879	12.623	9.695	2.414	15.443
320	22.597	17.432	13.039	10.053	2.506	16.030
330	23.383	17.984	13.456	10.412	2.599	16.621
340	24.171	18.537	13.874	10.772	2.692	17.217
350	24.961	19.089	14.292	11.135	2.786	17.816
360	25.754	19.640	14.712	11.499	2.880	18.420
370	26.549	20.192	15.132	11.865	2.974	19.027
380	27.345	20.743	15.552	12.233	3.069	19.638