NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING

INDUSTRIAL INSTRUMENTATION AND CONTROL 1

TIE 3114

Main Examination Paper

December 2014

This examination paper consists of 6 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Graph paper

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<u>INSTRUCTIONS</u>

1. Answer any five (5) questions.
2. Each question carries 20 marks.
3. Use of calculators is permissible.

Question 1

A displacement transducer with a shaft stroke of 20*cm* shown in Figure Q1 is used to measure displacement. The terminal of the shaft connected to the positive is termed A, and the one connected to the negative is termed B. The total resistance of the element making up the shaft is 400Ω.The voltage source, $V_{in}$is 4*V*. Resistance is uniformly distributed along the length of the element.

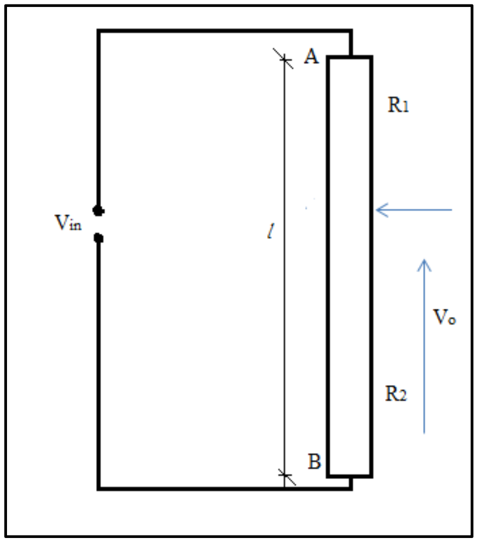

Figure Q1: Displacement transducer

a) If the wiper is at 15cm from B
   i) What is the value of *Vo*, [2]
   ii) What is the value of R_2, [2]
   iii) What is the value of*Vo* when the wiper is 7*cm* from B. [2]

b) Explain the following terms
   i) Dead zone, [2]
   ii) Range, [2]
   iii) Precision, [2]
   iv) Accuracy. [2]

c) Describe the principle of operation of an optical shaft encoder with a coded disc. [6]

Question 2

a) Define the term resolution. [2]

b) Determine

   i) The resolution of an 8 bit register converted into a voltage in the range of 0 to $10V$. [3]

   ii) What is the value that represents 4 Volts? [3]

c) Redundancy is a critical element in the design of SCADA systems.

   i) What is it? [2]

   ii) Describe how it can be implemented. [4]

d) Show using a clearly labelled sketch the basic architecture of a micro-controller. [6]

Question 3

a) What is sensitivity? [2]

A load cell is calibrated in an environment at a temperature of $21°C$ and has thefollowing deflection/load characteristic:

Table Q3 (a): Deflection vs load characteristics

Load (Kg)	**0**	**50**	**100**	**150**	**200**
Deflection(mm)	**0.0**	**1.0**	**2.0**	**3.0**	**4.0**

When used in an environment at $35°C$, its characteristic changes to the following:

Table Q3 (b): Deflection vs load characteristics

Load (Kg)	**0**	**50**	**100**	**150**	**200**
Deflection(mm)	**0.2**	**1.3**	**2.4**	**3.5**	**4.6**

b) Determine the sensitivity at $21°C$ and $35°C$. [4]

c) Calculate the total zero drift and sensitivity drift at $35°C$ [4]

d) You have been assigned to work at a chemicals manufacturing plant. It has been brought to your attention that there has been a perennial problem with the flow rate measurement system. Investigations that had been carried out earlier revealed that the components of the turbine flow meter inside the pipe were reacting with the corrosive liquid whose flow was being measured. Given that the chemical in question is a conductive liquid

   i) Suggest the appropriate measuring instrument that you would recommend and justify your choice. [4]

   ii) Describe the principle of operation of the instrument you chose. [6]

Question 4

Figure Q4 below shows the circuit in which the voltage across$R_5$is to be measured and the equivalent circuit by Thevenin's theorem

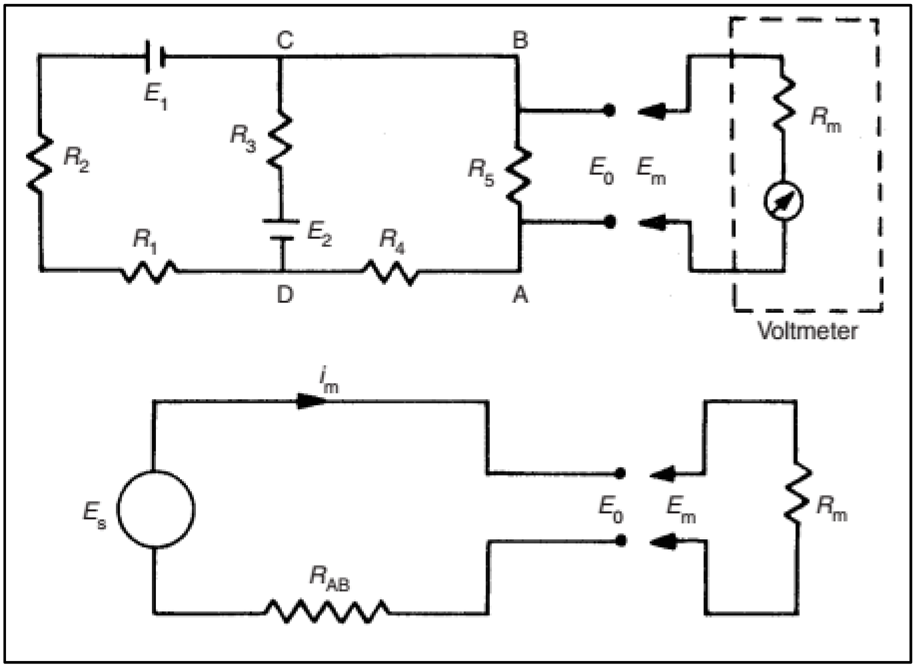

Figure Q4: Voltage measurement circuit

Suppose that the components in the circuit shown in Figure Q4above have the following values: R_1=330, R_2=1000, R_3=1200, R_4=220, R_5=270

a) If the instrument measuring the output voltage across AB has a resistance of 5000 Ω, what is the measurement error caused by the loading effect of this instrument? [10]

b) State three methods that are used to reduce the effects of stray magnetic fields in electrical measurement systems. [3]

c) By means of a clearly labelled diagram explain the principle of operation of a rotameter. [7]

Question 5

a) What are interrupts? [2]

b) Give two practical example of where interrupts can be used and describe their use in each case. [4]

c) A PLC has five basic components. Show using a block diagram how these functional elements are interconnected and describe the function of each component. [10]

d) What factors would you consider when choosing a PLC? [4]

Question 6

Figure Q6 below shows the schematic of a mixing plant. When the plant was initially installed, emptying the silos was done manually. A plan to automate the plant was proposed and you were tasked to lead the project. The process engineer gave you the following specifications:

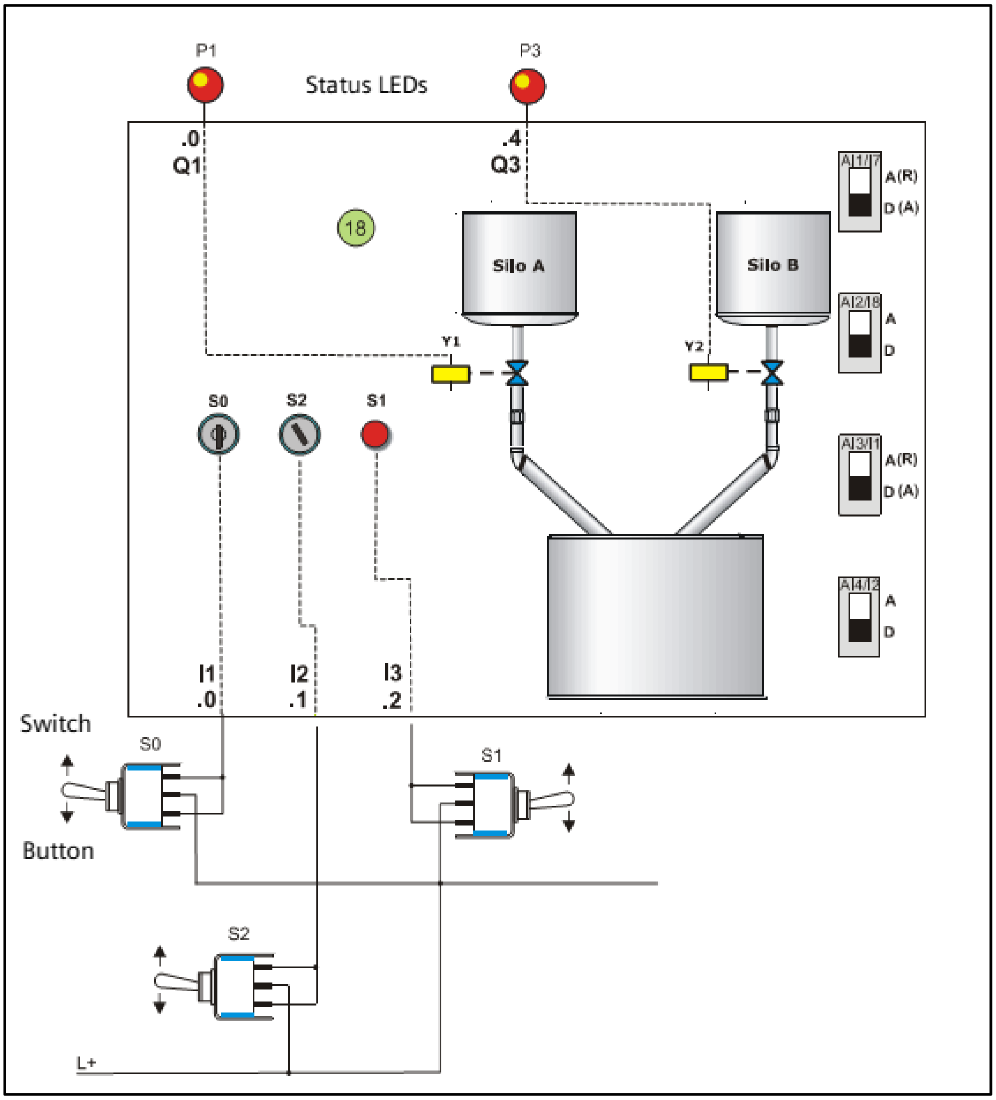

Fig Q6: Mixing plant

The selection switch S2 allows a choice of two types of bulk goods in a mixing plant. At switch position A (S2 = L-signal) bulk goods A are delivered to a mixing tank if button S1 is pressed simultaneously. Bulk goods B are transported likewise if selection switch S2 is at position B (S2 = L-signal) and button S1 is pressed simultaneously. The dispensing process is switched-off with switch S0.

Table Q6: Correlation list

Correlation list 1		
Symbol	**absolute**	**Comment**
S0	E 0.0	Switch
S1	E 0.1	Button
S2	E 0.2	Selection switch
Y1/P1	A 0.0	Valve bulk goods A
Y3/P3	A 0.4	Valve bulk goods B

From the process engineer's specifications you are required to:-

a) Draw the flow diagram for the operation of the mixing plant. [10]

b) Draw the ladder logic diagram for the operation of the garage. [10]

Question 7

a) In a.c bridges, what are the two conditions that must be satisfied simultaneously to achieve balance? [2]

b) A Hay bridge is often used for measuring the inductance of high Q- coils (i.e. Q>10) and has a configuration shown in Figure Q7 below.

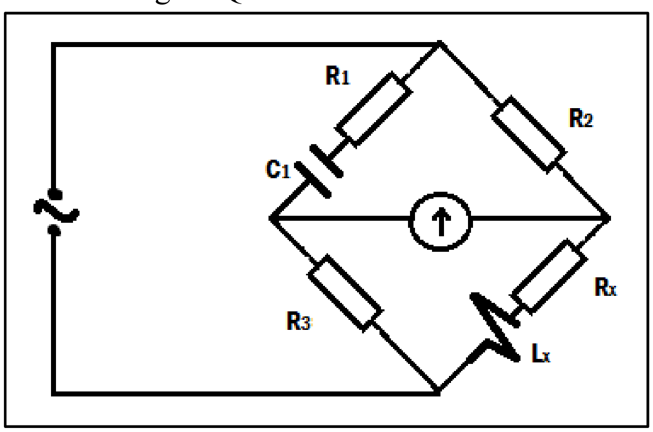

Figure Q7: Hay bridge

i) If the bridge is balanced, find the unknown R_x and L_x in terms of the circuit components [6]

ii) Calculate the value of the inductor if the bridge components at balance are as follows: $R_1 = R_2 = R_3 = 1000\Omega$, $C_1 = 0.02\mu F$ and $f = 10$ kHz. [4]

c) With the means of a clearly labelled diagram, explain the principle of operation of a Linear Variable Differential Transformer (LVDT) and suggest one possible application. [8]

End of examination paper