Unit 4 - Week 3

Week 3 Assignment on Temperature Measurements

1) For a K-type thermocouple, thermoelectric voltage at 50 °C and 500 °C are 2.023 mV and 20.644 mV, respectively when the reference junction is kept at 0 °C. Thermoelectric voltage versus temperature relation is approximated as, \( e_{0-T} = aT + bT^2 \). For certain temperature \((t_1)\) of the hot junction, the thermocouple shows 10 mV, with the reference junction at 25 °C. Find, the unknown temperature ‘\(t_1\)’ of the hot junction.

- a) 269.4 °C
- b) 278.5 °C
- c) 298.7 °C
- d) None of these

Accepted Answers:
- a) 269.4 °C

2) Resistance-temperature relation for a thermistor is given by, \( R = R_0 \exp \left[ \beta \left( \frac{1}{T} - \frac{1}{T_0} \right) \right] \)

where ‘\(R\)’ is resistance of thermistor at temperature ‘\(T\)’, \(R_0\) is resistance of thermistor at temperature \(T_0\). \(\beta = 3800\) K, is a constant for a particular thermistor. It is known that \(T_0 = 25\) °C, \(R_0 = 1250\) Ω ± 5 %. Calculate the maximum error in measurement if temperature \(T = T_1\), if resistance \(R\) at temperature \(T_1\) is measured to be 2000 Ω.

- a) 0.98 K
- b) 1.64 K
- c) 1.11 K
- d) 1.06 K

Accepted Answers:
- c) 1.11 K
3) Based on Figure 1., answer question (3) and (4)  

Assume $\alpha = 1$, find the normalised sensitivity (of $e_o/e_{ex}$) of the circuit for very small $x$.

- a) 0.25
- b) 0.5
- c) 0.75
- d) 1.0

**Accepted Answers:**
- a) 0.25

4) If it is required to keep the maximum non-linearity within 5% over the range of between 0 and 0.5, then evaluate the minimum value $\alpha$.

- a) 7
- b) 8
- c) 9
- d) 10

**Accepted Answers:**
- c) 9

5)
If the circuit in Figure 2 is used in place of Figure 1, for RTD signal conditioning, then find out (i) the normalised sensitivity \( \frac{e_o}{e_{ex}} \) of the circuit with respect to \( x \) and (ii) maximum non-linearity of the output voltage \( V_o \).

![Figure 2](image)

\[
2R(1+x)
\]

\[
\begin{align*}
R & \quad e_{ex} \\
\frac{R}{2} & \quad e_o \\
2R & \quad e_{ex}
\end{align*}
\]

6)

Accepted Answers:

- a) (i) 0.25; (ii) 0 %
- b) (i) 0.67; (b) 0 %
- c) (i) 0.5; (ii) 0.25 %
- d) (i) 0.5; (ii) 0 %

Figure 3 shows two circuits for improving the linearity of thermistor response. If the maximum allowable non-linearity is 2%, then which of the two circuits can be used for a larger input range? (Assume, \( R_1 = R_2 = R \) and \( R_T = RX(1+x) \))

![Figure 3](image)

(a) \hspace{2cm} (b)

- a) circuit (a)
- b) circuit (b)
- c) Both have same input range
- d) Insufficient data

Accepted Answers:

- b) circuit (b)
The following circuit, in Figure 4, is used to measure temperature using a Pt-100 RTD \( R_t \) (assume, 1st order resistance-temperature relation for the RTD). The constant current source provides 1 mA current. Resistances of the lead wires are, \( R_{L1} = R_{L2} = 0.6 \, \Omega \) and \( R_L = R_{L4} = 0.7 \, \Omega \). If the voltmeter shows 138.5 mV, what is the measuring temperature \( \text{Temperature coefficient of resistance } \alpha = 0.00392 \, \Omega/\Omega \cdot ^\circ C \)

\[ R_t = (R_{L1} + R_{L2} + R_{L3})/3 \]

\[ e_O = (e_1 + e_2 + e_3) \]

\[ e_O = (e_1 \times e_2 \times e_3) \]

\[ \text{d) None of these} \]

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Figure 5 shows a parallel combination of thermocouples. \( e_1, e_2 \) and \( e_3 \) are the generate thermoelectric voltages at the output of the individual thermocouples as shown in the figure. Determine the expression for voltage \( e_0 \) as shown in the figure.

\[ e_0 = (e_1 + e_2 + e_3) \]

\[ e_0 = (e_1 \times e_2 \times e_3) \]

\[ \text{d) None of these} \]
Accepted Answers:

\[ e_0 = \frac{e_1 + e_2 + e_3}{3} \]