SE104 Homework 5

1. For strain measurement, we want to achieve the accuracy of $10^{-6}$. For instance, for a 1-cm-long specimen, we need to detect its length change as small as $10^{-6}$ cm, i.e. 10 nm. Assume the gauge factor (GF) of a strain gauge is 2. By using a Wheatstone bridge, we measure the resistance change of the strain gauge ($dR/R$) to calculate the strain ($dL/L$). The smallest electrical resistance change that we can measure is $2\times10^{-4}$ Ohm. (a) How large does the initial resistance of strain gauge ($R$) need to be, so that our resistance measurement resolution ($2\times10^{-4}$ Ohm) is sufficient for the strain measurement? (b) If the strain gauge is made of constantan and the wire thickness is 0.025 mm, how long should the total wire be? Hint: the resistivity of constantan is $49\times10^{-8}$ Ωm. (c) How can this long wire be arranged to measure the average strain of a 1×1 cm small area?

2. A Wheatstone bridge is formed by 1 strain gauge ($R_1$) and three resistors ($R_2$, $R_3$, and $R_4$). The initial resistance of all of them are the same 120 Ohm. The gauge factor of the strain gauge (GF) is 1.5. The applied voltage ($E_i$) on the Wheatstone bridge is 10 V. Initially, the bridge is balanced. After the strain gauge deforms, the bridge output ($\delta E_0$) is measured as 10 mV. What is the strain?

3. A Wheatstone bridge is shown above. $R_1$, $R_2$, $R_3$, and $R_4$ are four strain gauges having the same initial resistance 120 Ω. Their gauge factors are 2. They are mounted on a rod. The Young’s modulus of the rod material is 200 GPa and the Poisson’s ratio is 0.3. The rod diameter is 10 cm and its length is 1 m. The rod is subjected to a tensile force. Gauges 1 and 4 are mounted along the axial direction, i.e. the loading direction. Gauges 2 and 3 are mounted along the transverse direction. The applied DC voltage on the bridge $E_i = 10$ V. The bridge output $\delta E_0 = 40$ mV. (a) What is the engineering strain along the loading direction? (b) What is the tensile stress?

4. We have 4 identical strain gauges of the same initial resistance ($R$) and the same gauge factor (GF). They will be used as $R_1$, $R_2$, $R_3$, and $R_4$ in a Wheatstone bridge, respectively. We want to measure the tensile strain of a rod subjected to a tensile force. What is the maximum bridge constant ($\kappa$) that we can reach? Clearly state your assumptions.

5. Describe at least one method to eliminate the thermal mismatch effect in strain-gauge measurement.

Bonus Question: List two common reasons that may cause failure in strain measurement using strain gauges. Do a literature review if needed.