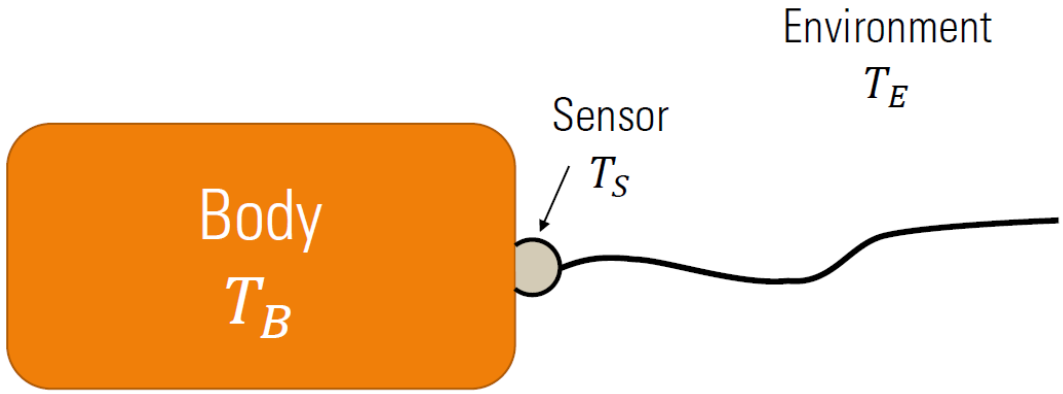
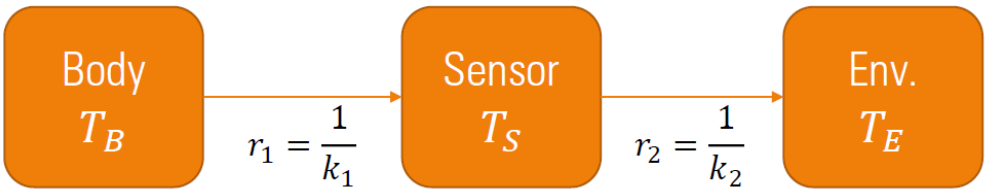
Transducer and Instrumentation – Assignment 08

1. Consider the following temperature measurement system. The body has mass M_B, has a specific heat capacity C_B, and the sensor has a mass M_S, has a specific heat capacity C_S. If the sensor has been in contact with the body for a long enough time derive the expression for the final temperature of the body and the sensor. Assume that the environment has infinite specific heat capacity, and its temperature remains the same. Also, that there is no direct loss of heat from the body to the environment.





2. In the system described above, we are interested in knowing the dynamics of the temperature of the body and the sensor. Assume that the body and sensor temperatures at time t is given by $T_B(t)$ and $T_s(t)$. If the sensor is placed on the body at time $t = 0$, derive the expression for the temperatures of the body and the sensor as a function of time for $t > 0$.

3. A Wheatstone bridge can be used for measuring the changes in resistance of an RTD as a function of temperature. Assuming the following linear model for the RTD resistance,

$$R_{T_1} = R_{T_0}[1 + \alpha_0(T_1 - T_0)]$$

Assume that we know R_{T_0} at temperature T_0. We are interested in measuring T_1. Consider the following two Wheatstone bridges with two and three lead wires. The lead wires are also affected by temperature the sensor is exposed to. Assume that the resistance R_1, R_2 and R_4 is chosen such that the bridge is balanced at temperature T_0. When the temperature of the sensor changes, the bridge will be unbalance. Derive the expression for the voltage V_0. Assume that the change in the lead wire resistance for

wires A and B is the same as the temperature changes from T_0. Find the expression for estimating the temperature from V_0.

Derive the expression for V_0, assuming the bridge was balanced at T_0. Find the expression for estimating the temperature from V_0. What is the advantage of the three-lead wire arrangement, compared to the two lead wire arrangement?

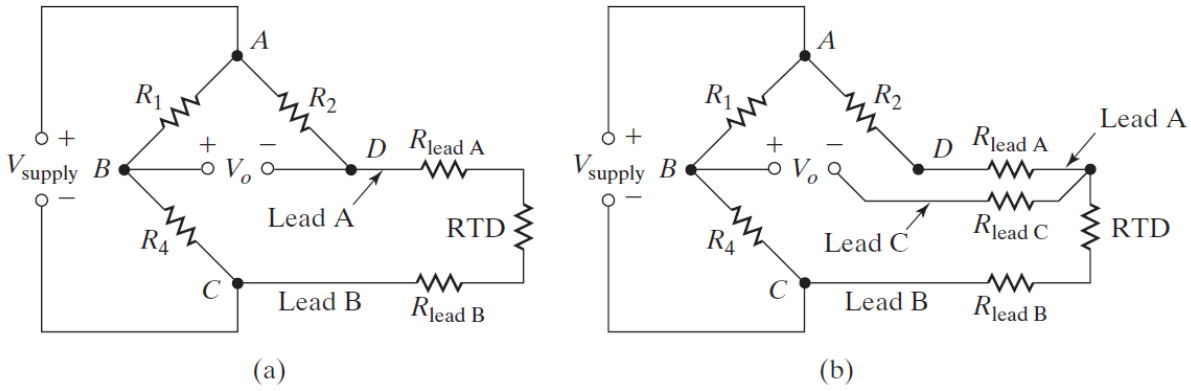
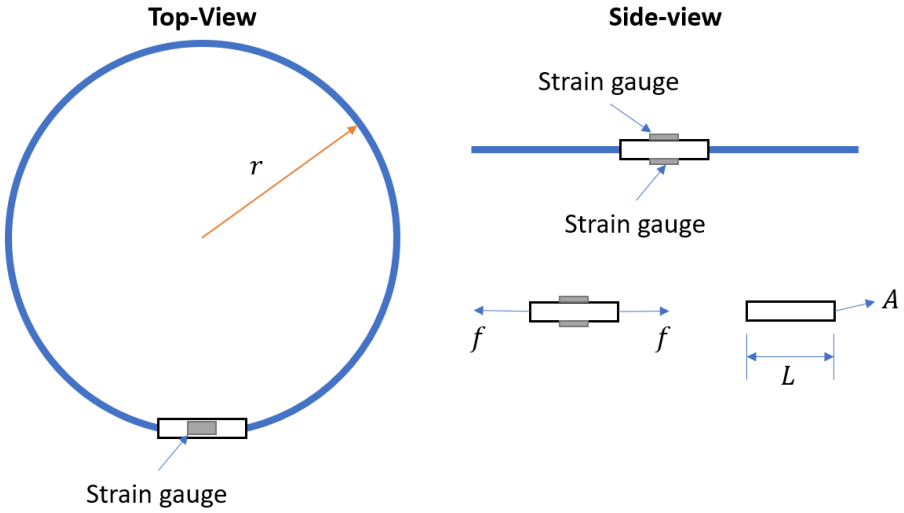


FIGURE 9.21

Wheatstone bridge circuits for RTD: (a) two-wire; (b) three-wire.

4. Consider the following sensing system consisting of a linear elastic band, with its two ends attached to the ends of a beam containing strain gauges, at the top and bottom surfaces, oriented along the length of the beam.



The force acting on the two ends of the beam is given as the following,

$$f = k \cdot 2\pi \cdot (r - r_0)$$

where, r_0 is the radius of the elastic band at where there is no force acting on the beam, and $r \geq r_0$. Assuming the cross-sectional area, length, and the Young's modulus of the beam are A, L, and E, respectively. The gauge factor of the two strain gauges is S_s.

If you have five of these sensing systems with the same characteristics, explain how you can use them to measure the change in volume of an object that as circular cross-section, with possibly varying radius of cross-section along its length. This object can

undergo a change in its cross-section radium. Discuss the details of the sensing circuit you will need to measure change in radium of cross section of the object. How can you use this change to compute the change in the volume of the object.