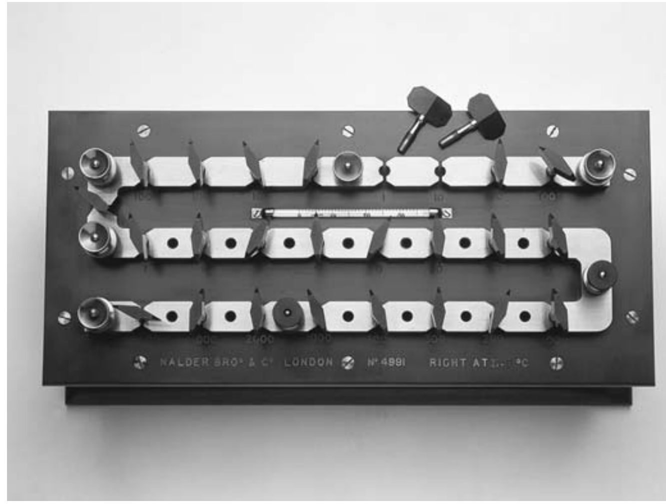


The Cooke and Wheatstone Bridge

Credit: Science Museum/Science & Society Picture Library, London.

This measurement device was introduced to the Royal Society in 1843 in a paper *An Account of Several New Processes for Determining the Constants of a Voltaic Circuit* by Charles Wheatstone (1802-1875), an English physicist and Professor of Experimental Philosophy at King's College, London. In that paper he also introduced a unit of resistance based upon a 1 foot length of copper weighing 100 grains. The device, which was known in the 19th century as the Cooke and Wheatstone bridge, produced by the entrepreneur William Cooke and Wheatstone. Samuel Christie actually was the first person to described the bridge in 1833. Now it is known simply as the Wheatstone bridge. The bridge employs two voltage dividers connected to a voltage source to measure resistance. One divider is made up of one known and one unknown resistor. The other is made up of two more known resistors. Using this configuration, the value of the unknown resistor can be determined.

The Wheatstone Bridge

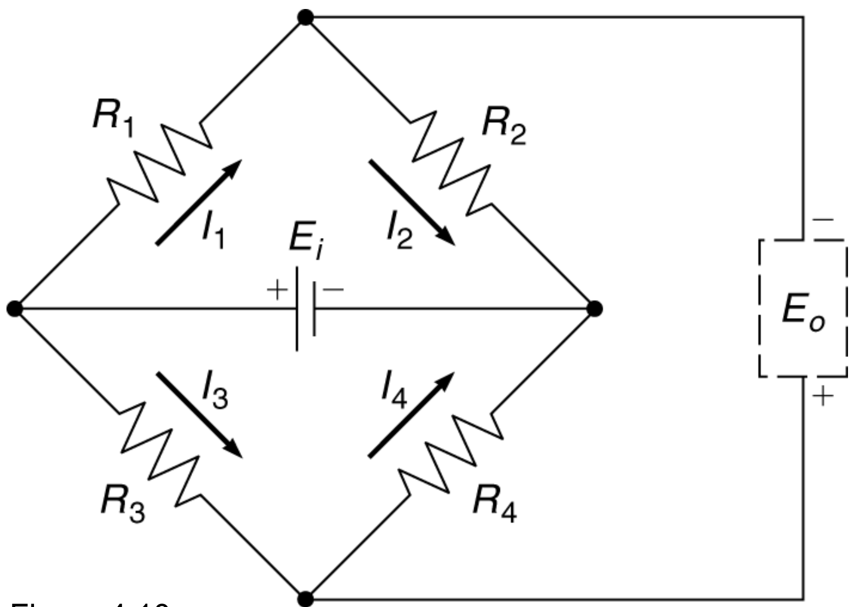


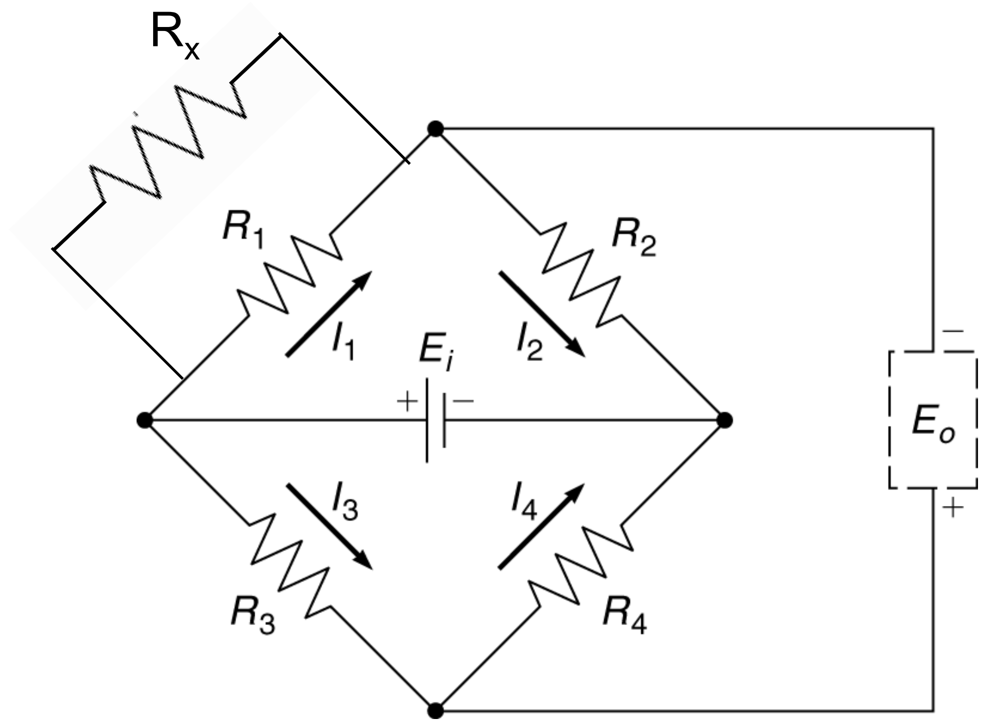
Figure 4.10

Use Kirchhoff's Voltage Law:

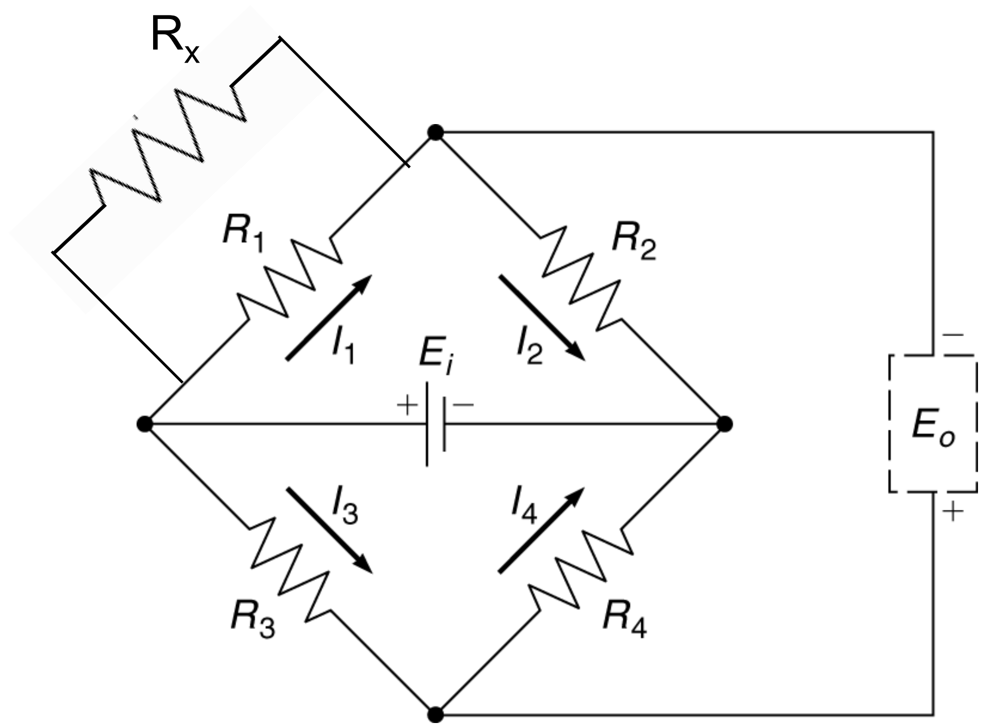
Combining these equations gives

$$E_o = E_i\left[\frac{R_1}{R_1 + R_2} - \frac{R_3}{R_3 + R_4}\right]$$

- What is the Wheatstone bridge equation if another resistor, R_x, is added in *parallel* with R_1 ?



- One advantage of using two resistors in parallel in one leg of the WB is that the added resistor can be located remotely from the actual WB, such as in a flow. Here, that resistor can serve as a sensor.



$$E_o = E_i\left[\frac{R_1}{R_1+R_2}-\frac{R_3}{R_3+R_4}\right]$$

- When $E_o = 0$, the WB is 'balanced' →

- When the WB is balanced *and* 3 of the 4 resistances are known, the 4^{th} (unknown) resistance can be found using the balanced WB equation. The is called the *null method*.

$$E_o = E_i \left[\frac{R_1}{R_1 + R_2} - \frac{R_3}{R_3 + R_4} \right]$$

- Now consider the case when all 4 resistors are the same *initially* and, then, one resistance, say R_1 is changed by an amount δR. This is called the *deflection method*.

- Often, δR is associated with a change in a physical variable.

Cantilever Beam with Four Strain Gages

- From solid mechanics, for a cantilever beam, ε_L or ε_C ~ F

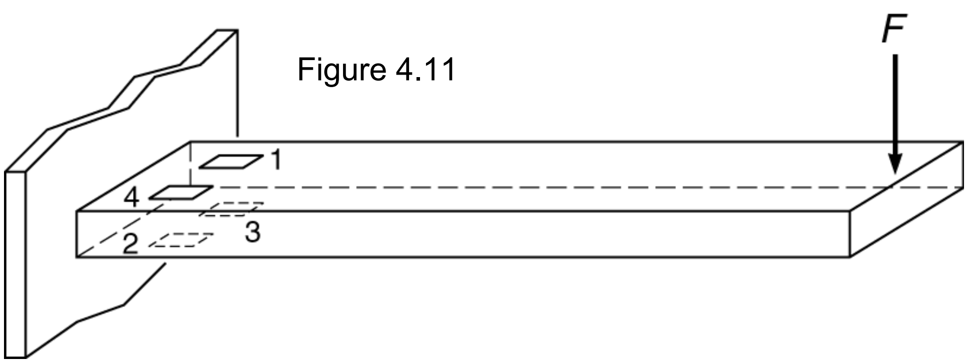


Figure 4.11

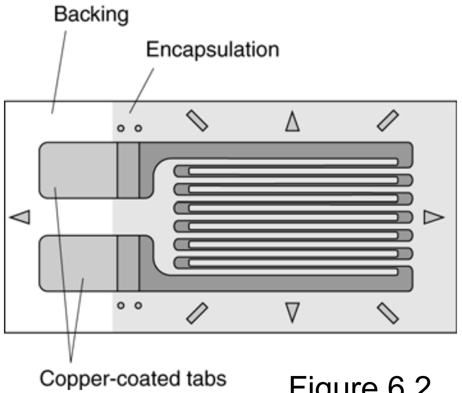


Figure 6.2

The Cantilever Beam with Four Gages

- The bridge equation $E_o = E_i \left[\frac{R_1}{R_1 + R_2} - \frac{R_3}{R_3 + R_4} \right]$

  becomes

- Because $\delta R \sim \varepsilon_L$ or $\varepsilon_C \sim F$, E_o = constant x F

  This is the voltage/force relation for a cantilever beam.

Loading Error

When measuring a voltage, the input impedance of the voltmeter must be much greater than the equivalent circuit’s output impedance.

When measuring a current, the input impedance of the ammeter must be much less than the equivalent circuit’s output impedance.