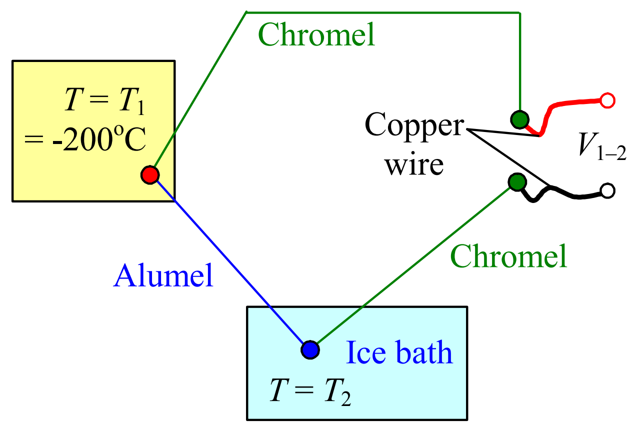
Today, we will:

- Continue reviewing the pdf module: **Temperature Measurement**
- Do some example problems – thermocouples, bulb thermometers, RTDs, thermistors

Example: Thermocouples



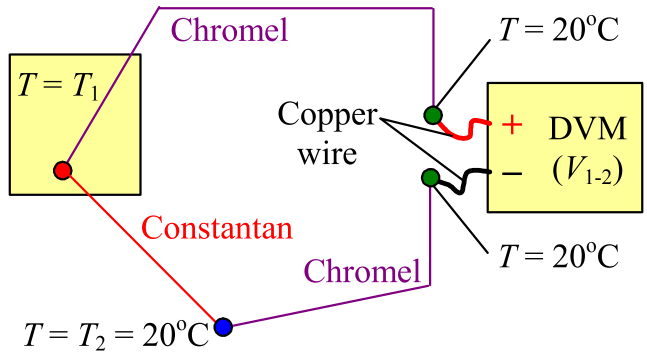
Given: Fred uses a type K thermocouple to measure the temperature in a freezer. The actual (*true*) temperature in the freezer is T_1 = -200.0°C. The thermocouple voltages are measured properly with an ice bath reference. Unfortunately, the ice bath has too much water, and its temperature is actually 1.00°C instead of 0.00°C. Fred is not aware of this – he assumes that the ice bath is at 0.00°C.

To do: Calculate the temperature that Fred measures, and the percentage error. Use the "brief" thermocouple tables for consistency.

Solution: Use our "workhorse" equation for thermocouples: $V_{1-2} = V_{1-R} - V_{2-R}$.

Example: Thermocouples

Given: James uses a type E thermocouple to measure the temperature of an oven. He has no ice bath, but uses a reference bath exposed to the ambient air, which he measures with a thermometer to be 20°C. The voltage James reads is 8.714 mV.



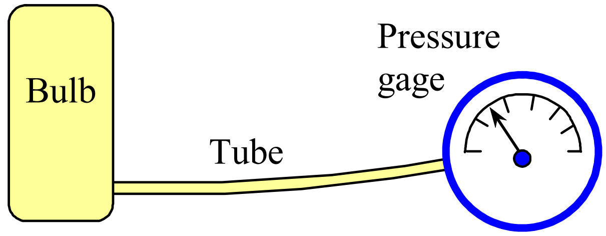
To do: Calculate the temperature in the oven. Use the "brief" thermocouple tables for consistency, a portion of which is shown here for convenience:

Temperature (°C)	T	E	J	K	R	S
0	0.000	0.000	0.000	0.000	0.000	0.000
20	0.789	1.192	1.019	0.798	0.111	0.113
40	1.611	2.419	2.058	1.611	0.232	0.235
60	2.467	3.683	3.115	2.436	0.363	0.365
80	3.357	4.983	4.186	3.266	0.501	0.502
100	4.277	6.317	5.268	4.095	0.647	0.645
120	5.227	7.683	6.359	4.919	0.800	0.795
140	6.204	9.078	7.457	5.733	0.959	0.950
160	7.207	10.501	8.560	6.539	1.124	1.109
180	8.235	11.949	9.667	7.338	1.294	1.273

Solution: Use our "workhorse" equation for thermocouples: $V_{1-2} = V_{1-R} - V_{2-R}$.

Example: Bulb thermometer

Given: A ***pressure thermometer*** (also called a ***gas thermometer*** or ***bulb thermometer***) relies on the ideal gas law $\boxed{PV = mRT}$ to calculate temperature T at a given measured pressure P (the gage is actually a pressure gage).



- V = volume of the gas in the bulb = constant
- R = ideal gas constant for the particular gas in the bulb = constant
- m = mass of the gas in the bulb = constant

(*a*) To do: Develop an equation for the ***sensitivity*** of the device. Is it constant? *Note*: Constant sensitivity implies that the output is a *linear* function of the input.

(*b*) To do: Determine whether a change in the *initial* filling pressure P_i and/or the *initial* filling temperature T_i have any effect on the sensitivity of the device.

Solution:

Example: RTDs

Given: A standard 100-Ω platinum RTD is used to measure the temperature of warm air in a tank. The resistance is measured to be 125.9 Ω.

To do: Calculate the temperature of the air in the tank.

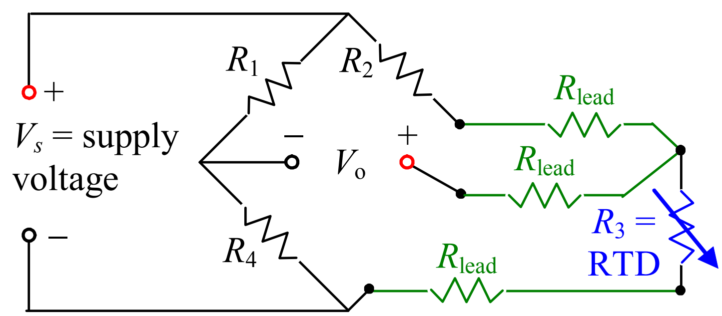
Solution: Need to interpolate. Here is a screen shot from the **Platinum 100-Ω RTD Table:**

°C	Ohms
65	125.16
70	127.07

Example: RTDs

Given: A standard 100-Ω platinum RTD is used to measure temperature. A Wheatstone bridge is set up in the three-wire configuration, using resistor R_3 as the RTD, as sketched.

- R_{lead} = 0.51 Ω at 20°C
- V_s = 10.00 V
- We want the bridge to be exactly balanced when T = 20°C

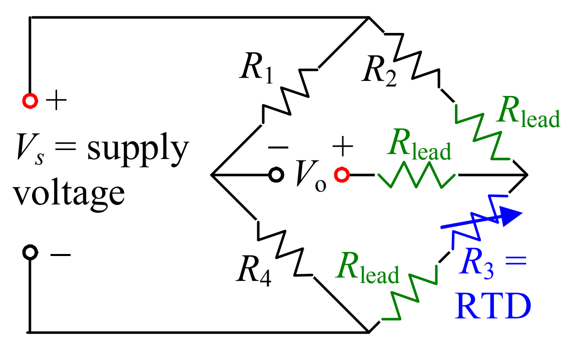


(*a*) To do: What resistors (R_1, R_2, and R_4,) should we use to balance the bridge at 20°C?

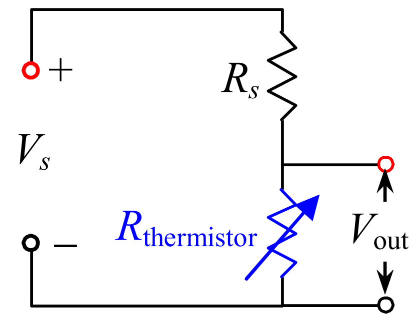
(*b*) To do: At T = 40°C, predict V_o. *Note*: At 40°C, R_{lead} increases slightly to 0.54 Ω.

Solution:

For clarity, we re-draw the circuit as shown to the right. Thus, $R_{2,total} = R_2 + R_{lead}$ and $R_{3,total} = R_3 + R_{lead}$.



Example: Thermistors



Given: A thermistor has a resistance of 1633$\underline{0}$ Ω at 0.0°C, and it drops to 624$\underline{7}$ Ω at 20.0°C. This thermistor is used in a simple voltage divider circuit, as sketched.

- V_s = supply voltage = 5.00 V DC.
- R_s = supply resistance = 10.00 kΩ.

(*a*) To do: Calculate the output voltage at T = 0.0°C.
(*b*) To do: Calculate the output voltage at T = 20.0°C.
(*c*) To do: Suppose the output voltage is 2.353 V. Estimate the temperature as best as you can, given the limited amount of information provided in the problem statement.

Solution: