

Writing an abstract

An abstract is a one-paragraph summary of your report.

- Basic introduction to the broad topic, readable by any colleague (1-2 sentences)
- Detailed motivation for solving the specific problem at hand, readable by engineers (2-3 sentences)
- Problem statement (1 sentence)
- Statement of your findings (e.g., “Here we show...”) (1 sentence)
- Implications of the result for the specific problem at hand (1-2 sentences)
- Broader implications for possible future problems, readable by any colleague (1-2 sentences)

A philosophy of captions

- Start with a brief and literal statement of what the figure shows (e.g., “Distributions of normalized resistance for different vascular arrangements.”).
- Give the reader all information necessary to understand what you’re plotting and how: colors, plot symbols, math symbols, acronyms, etc. But information that is self-evident in the plots, e.g. because it’s on legends or labels, need not be repeated.
- End the caption with a brief statement of the take-home message (e.g., “Though all distributions overlap with the observed normalized resistance, the hexagonal pseudorandom perturbed arrangement gives the closest match”).
- Don’t write “A figure showing...” or “Plots of ...” because that’s obvious.
- In the body text, avoid writing about colors or symbols; just write about the quantities.
- Keep details about the methods that produced the plots and the analysis of the results in the body text, not the caption...
- ... unless you’re writing with a tight word limit on body text (e.g. *Nature* or *Science*) and must therefore pack words into captions.

Radiation thermometers / thermal cameras

- All objects radiate always!

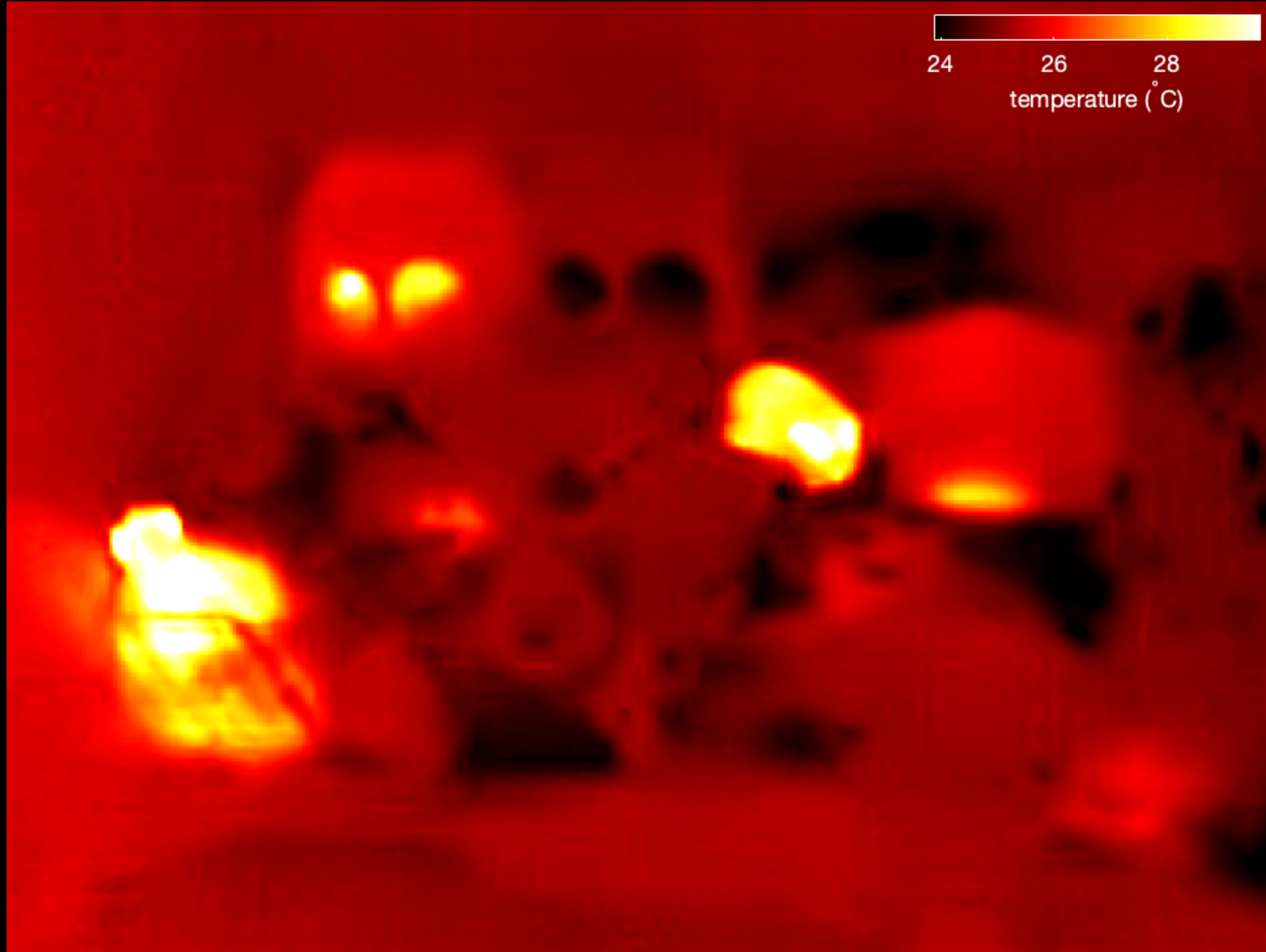
$$E = \epsilon \sigma T^4 = \epsilon \int_0^\infty \frac{C_1 \lambda^{-5}}{e^{\frac{C_2}{\lambda T}} - 1} d\lambda$$

radiation power E emissivity ϵ temperature T Stefan-Boltzmann constant $\sigma = 5.669 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$ wavelength λ

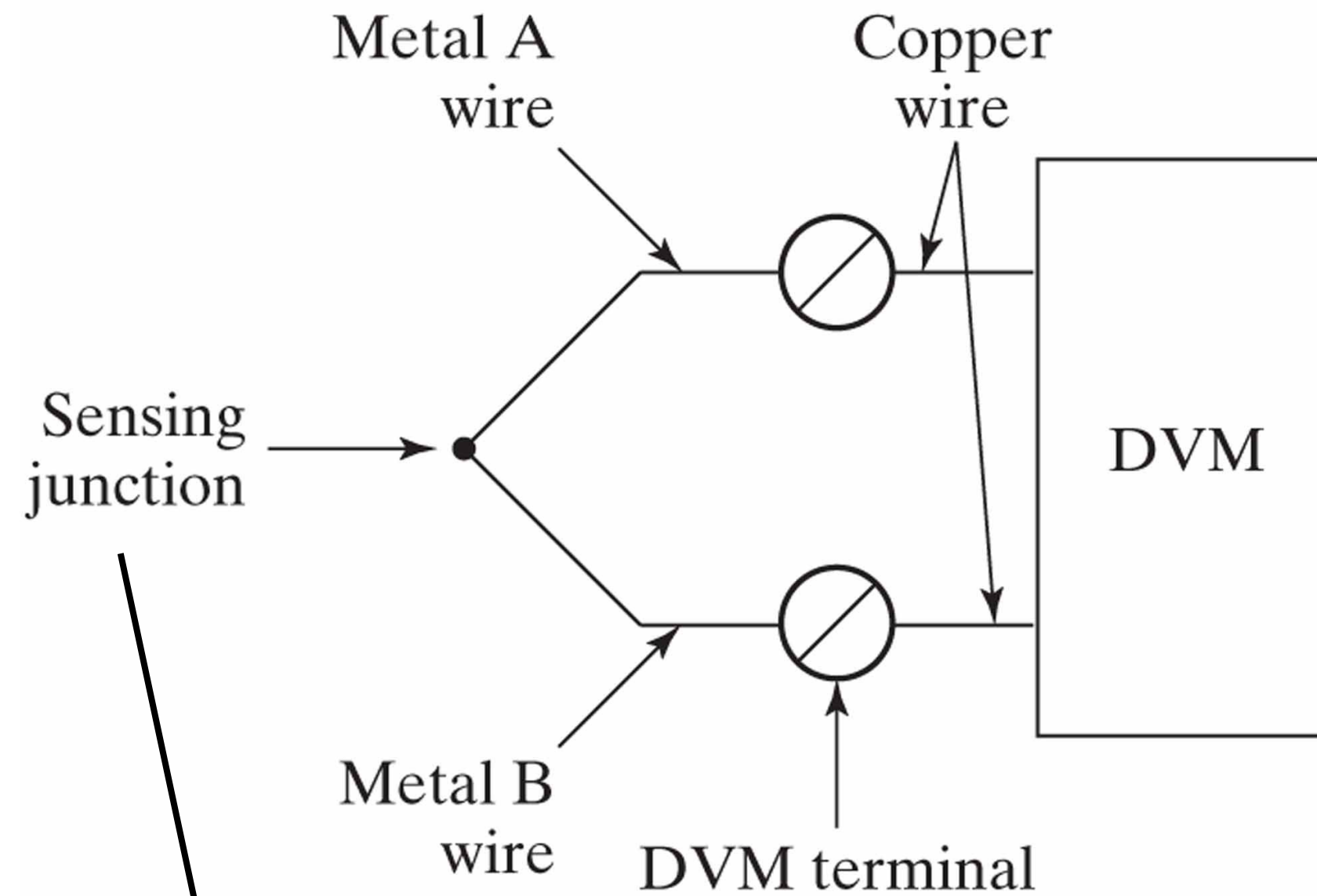
$C_1 = 3.743 \times 10^8 \text{ W} \cdot \mu\text{m}^4/\text{m}^2$
 $C_2 = 1.4387 \times 10^4 \mu\text{m} \cdot \text{K}$

- $\epsilon = 1$ for ideal black body, $\epsilon = 0.018$ for shiny metals
- Common to measure E at two or more wavelengths, estimate T from ratio.

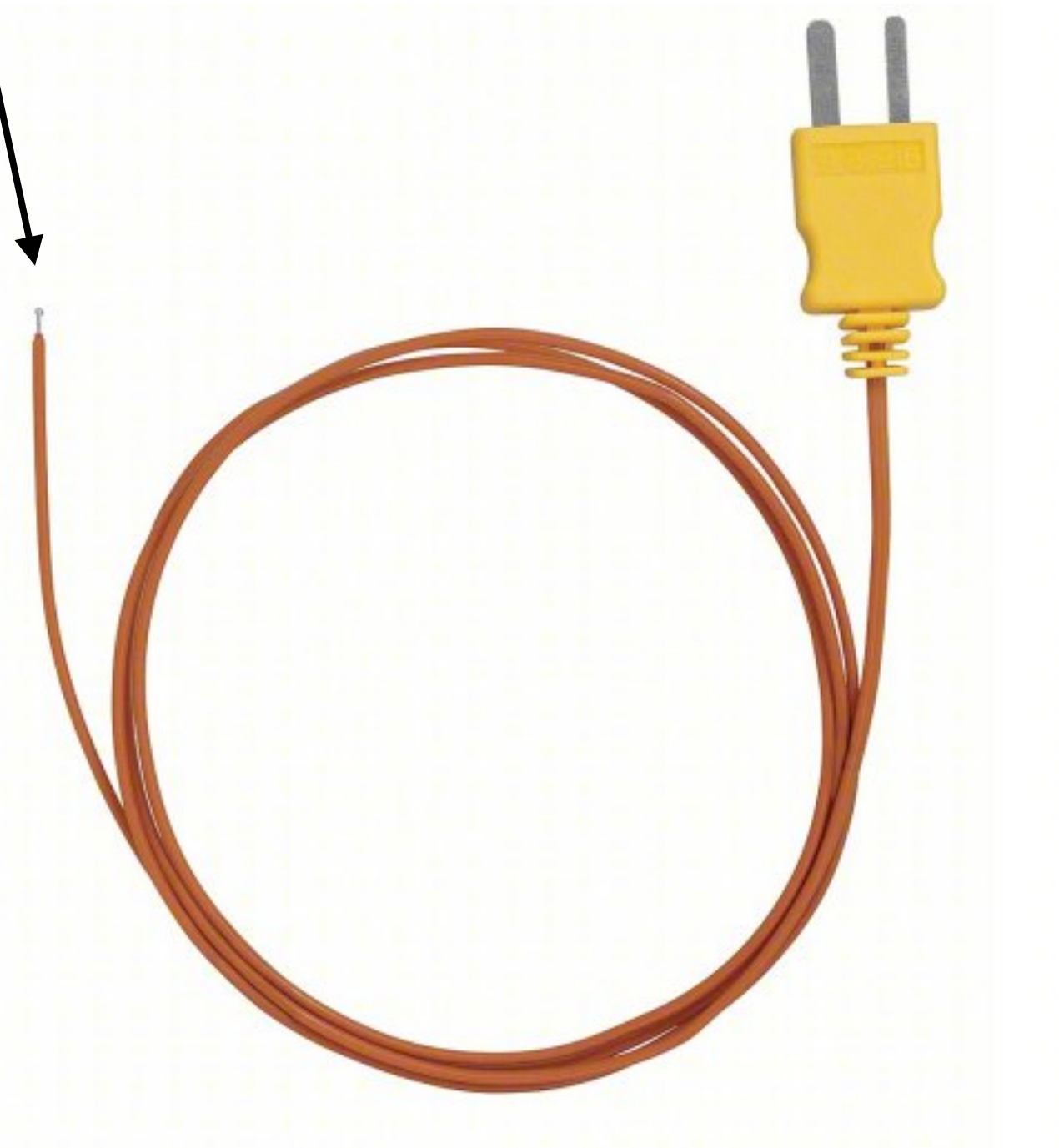
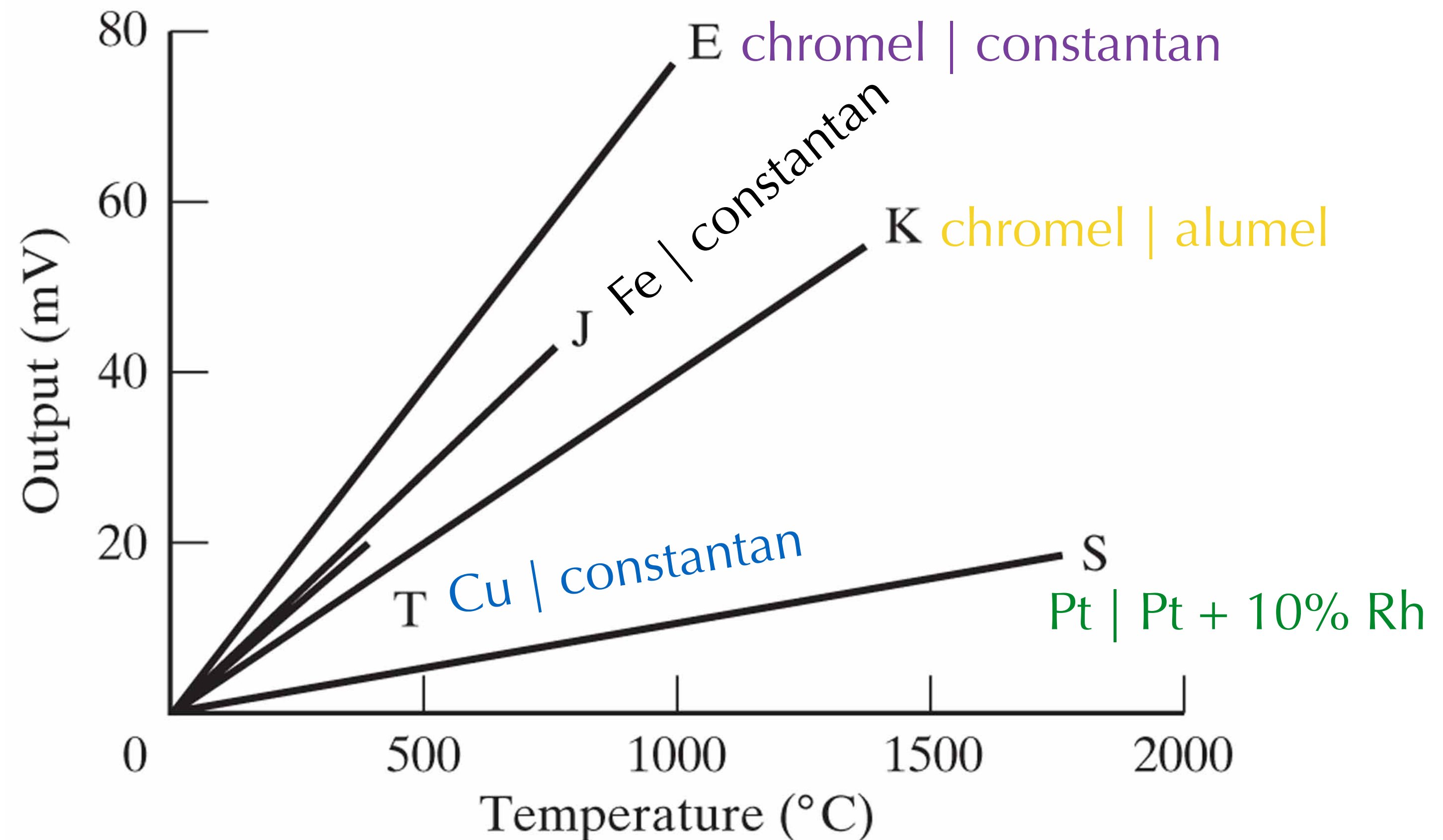




Thermocouples

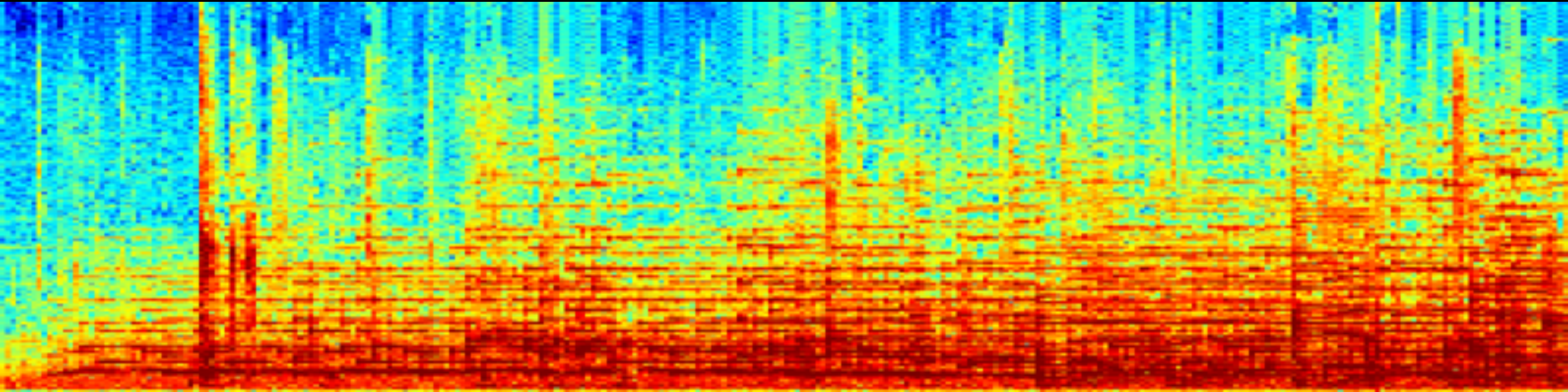


- Where two metals touch, a voltage is developed that is proportional to temperature (Peltier effect).
- Different proportionality for different metals.
- Lead wires of same (or compatible) metal



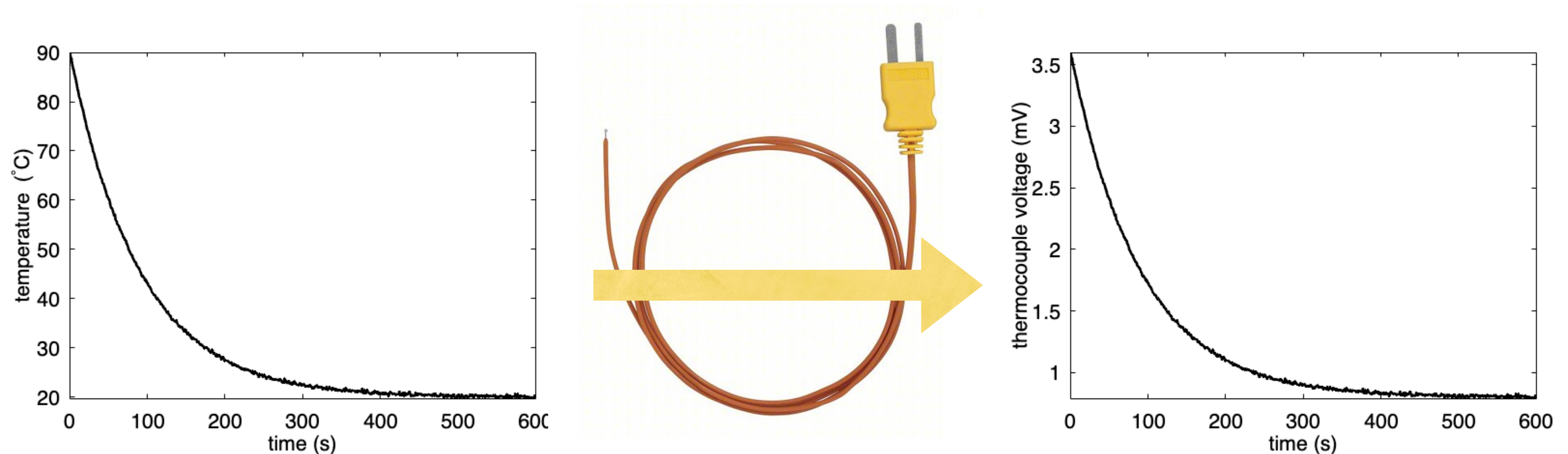
Computerized Data Acquisition Systems

Wheeler & Ganji Chapter 4



Analog signals

- A transducer produces a voltage related to the parameter being measured (often linearly), like an *analogy* to the original parameter



- Can vary continuously, take any value (real numbers), at any time
- But computers store and process discrete numbers, so must convert to digital

Binary numbers

- Decimal numbers: base 10
 - ... hundreds, tens, ones, tenths, hundredths, thousandths, ...
 - ..., 10^2 , 10^1 , 10^0 , 10^{-1} , 10^{-2} , 10^{-3} , ...
 - An N-digit integer can take any of 10^N values
- Binary numbers: base 2
 - ... sixteens, eights, fours, twos, ones, halves, fourths, eighths, ...
 - ..., 2^4 , 2^3 , 2^2 , 2^1 , 2^0 , 2^{-1} , 2^{-2} , 2^{-3} , ...
 - An N-bit integer can take any of 2^N values (N is called “bit depth”)
 - Most audio uses N=16. How many pressure values? $2^{16} = 65,536$
 - Grayscale images use N=8. How many shades of gray? $2^8 = 256$

Binary numbers

- Example: Convert 197 (decimal) to binary.
- $197 = 1 \times 10^2 + 9 \times 10^1 + 7 \times 10^0$
 $= 128 + 64 + 4 + 1$
 $= 1 \times 2^7 + 1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$
 $= 11000101$ (simple binary)
- For negative integers and floating-point numbers, use fancier schemes, but N bits always allow representing 2^N values.
- Linear simple binary mapping: $D_o = \text{int} \left\{ \frac{V_i - V_{rl}}{V_{ru} - V_{rl}} 2^{N-1} \right\}$

digital
output

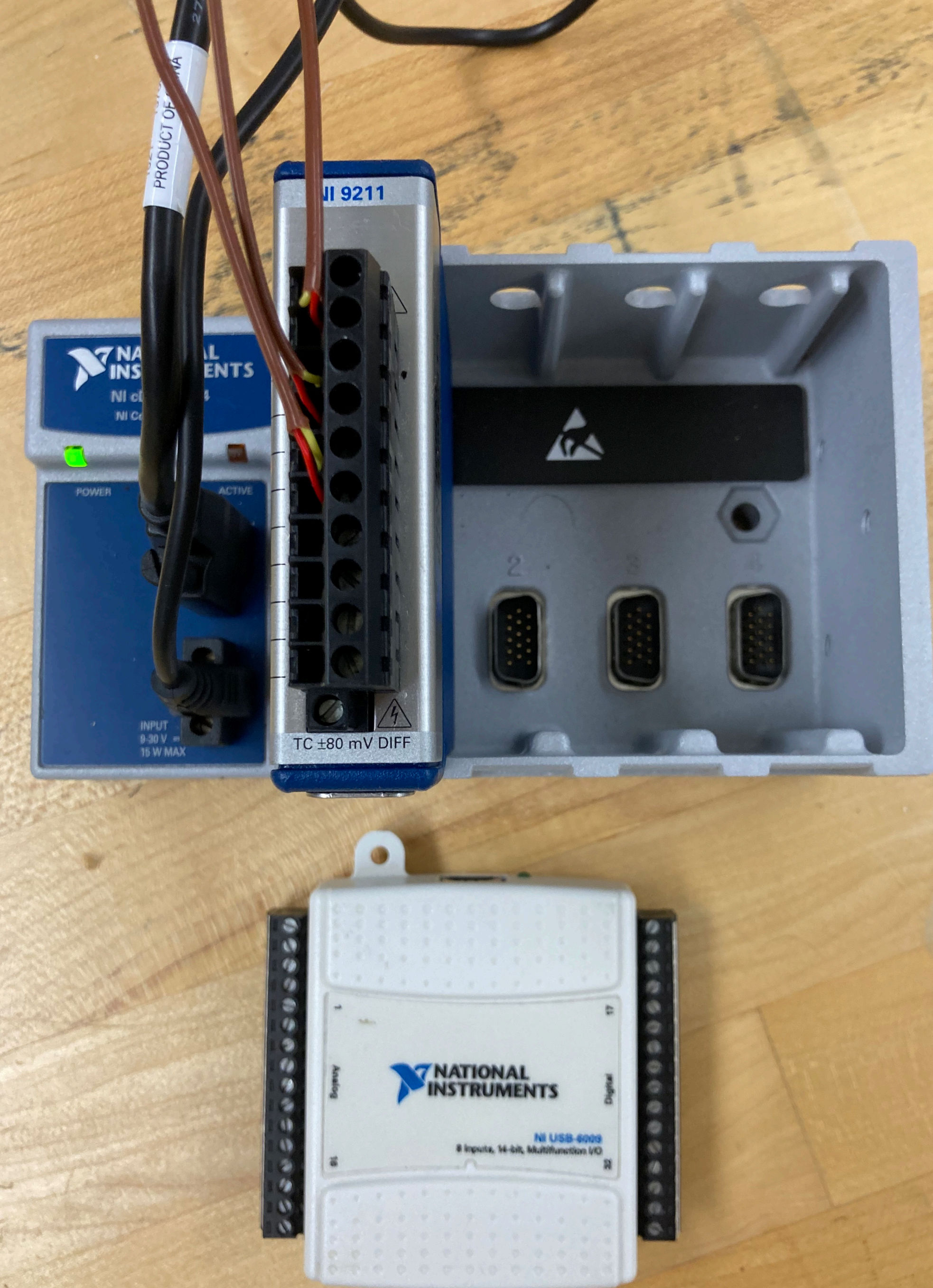
round to
nearest
integer

range
upper
end

range
lower
end
- Caution: misprint in Wheeler & Ganji

Computerized data acquisition⁴²

- Often connect via USB; sometimes internal
- Wires from transducers connect to screw terminals
- Range often -5 V to 5 V or 0 V to 10 V
- Special ports for thermocouples
- Analog inputs, digital input/output, occasionally analog outputs
- Varying channel count (1 to ~30), bit depth (8, 12, 16), sampling rates (~ 1 to $\sim 10^6$ S/s)
- Software interface (LabView, Matlab, ...)
- National Instruments, Measurement Computing, Keyence, Arduino, ...



Ex. 4.5: A 4-bit analog-to-digital converter has input range 0 to 10 V. Determine the digital output for an analog input of 6.115 V.

Quantization error

- Rounding to the nearest integer (or available value) causes error!
- A new, perfect (analog) vinyl record sounds better than an (digital, quantized) recording.
- Quantization Error = $\pm 0.5 \frac{V_{ru} - V_{rl}}{2^N}$
- Q: Systematic or random? **Random.**
- Quantization error is predictable. An audio recording on an old, worn CD or hard drive has the same quantization error as a new one (as long as it's readable at all). An old, worn vinyl record sounds much worse than a new one.
- Engineering trade-off: large N reduces quantization error but requires more storage space.