Schedule

08/31/17 (Lecture #1)
09/05/17 (Lecture #2)
09/07/17 (Lecture #3)
09/12/17 (Lecture #4)
09/14/17 (Lecture #5)
09/21/17 (4:00 – 18:30 h) (Lecture #6-7)
09/26/17 (4:00 – 18:30 h) (Lecture #8-9)
09/28/17 (Lecture #10)
10/03/17 (12:00 – 8:00 h) (Lab #1)
10/10/17 (12:00 – 8:00 h) (Lab #2)
10/20/17 (8:00 -17:00 h) (Lab #3)
10/24/17 (Q&A #1)
10/26/17 (Lecture #11)
11/07/17 (Q&A #2)
11/14/17 (Q&A #3)
11/21/17 (Q&A #4)
12/07/17 (Lecture #12): Term paper due on Dec. 14, 2017

- 12 lectures
- 3 long labs (8 hours each)
- 2-3 homework
- 1 group project
- 4 Q&A (Geography Room 206)

Diel t° change

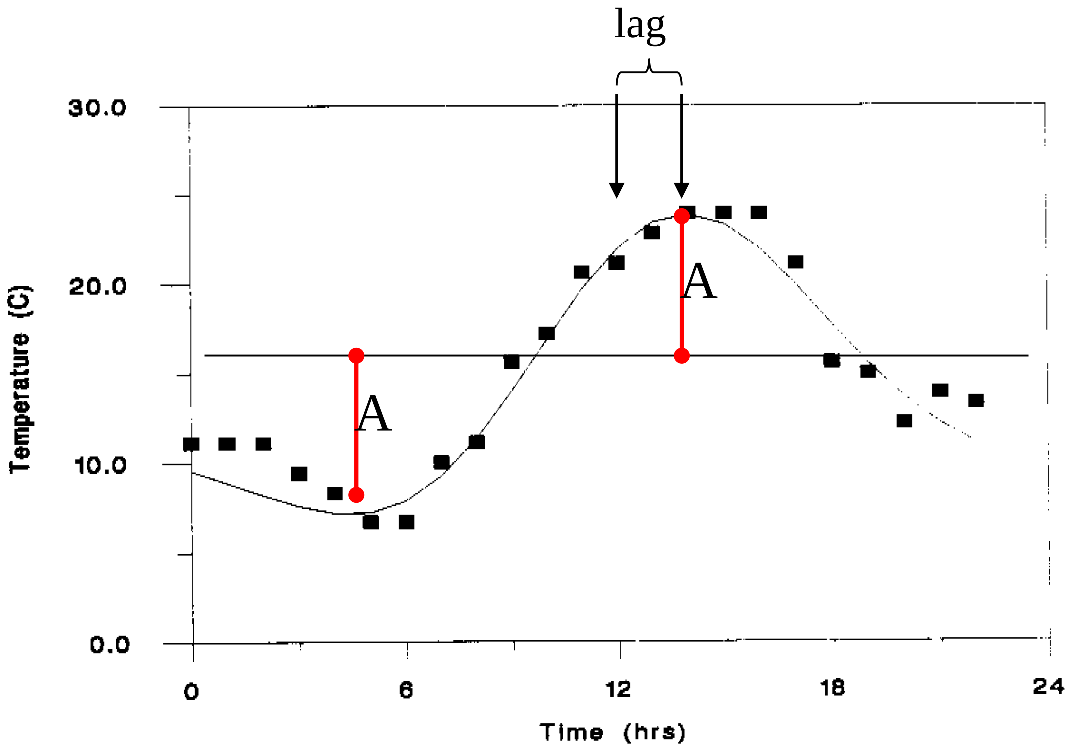
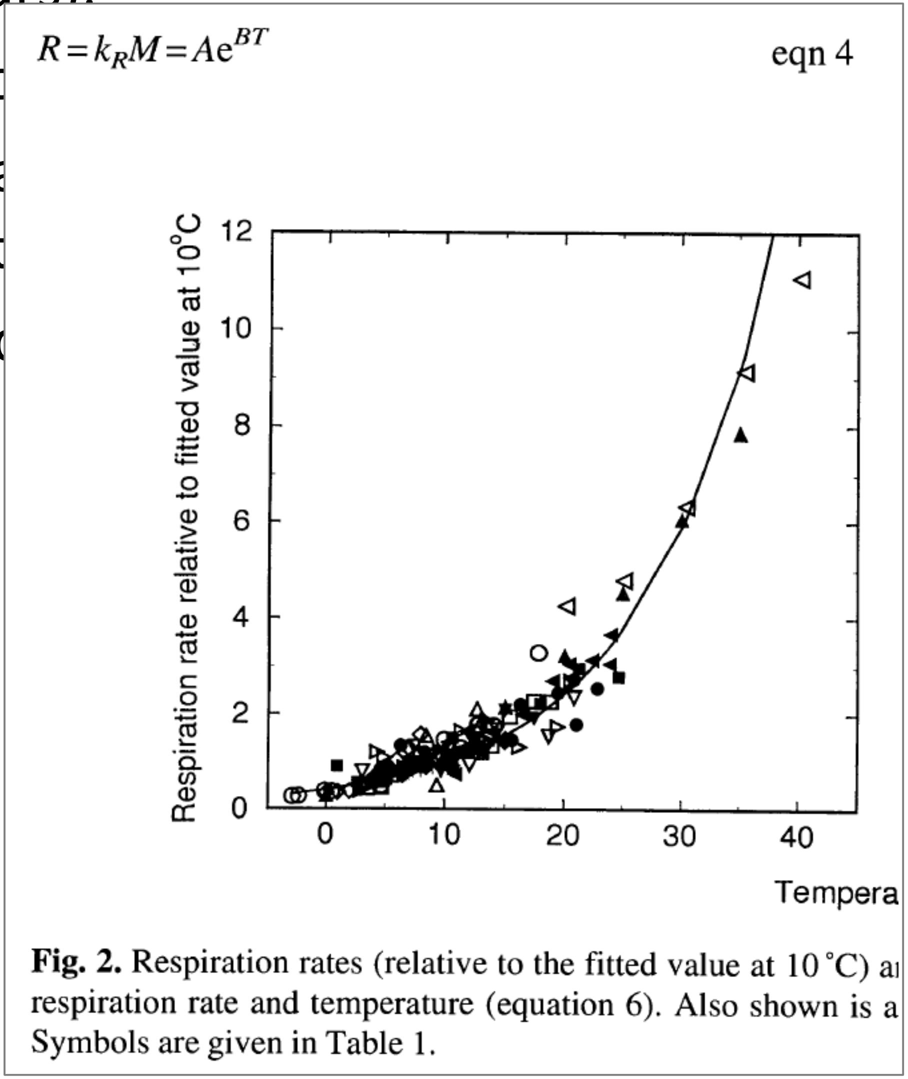


FIGURE 2.2. Hourly air temperature (points) on a clear fall day at Hanford, WA. The curve is used to interpolate daily maximum and minimum temperatures to obtain hourly estimates.

- t_{max} lags behind Φ_{max}
- Lag = f {d}
- Amplitude = f {d}

Applications in Ecology, Agriculture, Forestry, etc.

- Growing degree days (the temperatures above which certain plant/animal growth occurs).
- Phenology (temperature > 3 °C fo
- Growing season length (the avera
  with a 24-hour average temperat
- Biophysical models (e.g. Q10 mo



$$R = k_R M = Ae^{BT}$$ eqn 4

Fig. 2. Respiration rates (relative to the fitted value at 10 °C) a
respiration rate and temperature (equation 6). Also shown is a
Symbols are given in Table 1.

GEO892: Micrometeorological Instrumentation & Measurements (9/5/2017)

- Ohm’s Law: batteries, power supplies, and sensors
- Temperature (Chapter 2, Fritzchen 1979)
- Thermocouples: principles and applications
- Making thermocouples)
- Introduction of LoggerNet: various modules and uses?

Team Project & Term Paper

- Construct a microclimatic (& EC flux) station
- Collect at least 2 weeks data
- Analyze the data for results (figures and tables)
- Follow the instructions of *Ag. For. Met.*
- Due on Dec. 7, 2017

Ohm’s Law and Applications

Ohm’s Law

$$I = \frac{E}{R} \qquad \text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

- Ohm’s Law: I, V (E), R
- Series and parallel circuits
- Wheatstone bridge
- Power supplies: voltage change, tower application
- Thermopile
- Sapflow sensor

Ohm’s Law and Applications

Ohm's Law defines the relationships between (P) power, (E) voltage, (I) current, and (R) resistance. One ohm is the resistance value through which one volt will maintain a current of one ampere.

(I) Current is what flows on a wire or conductor like water flowing down a river. Current flows from negative to positive on the surface of a conductor. Current is measured in (A) amperes or amps.

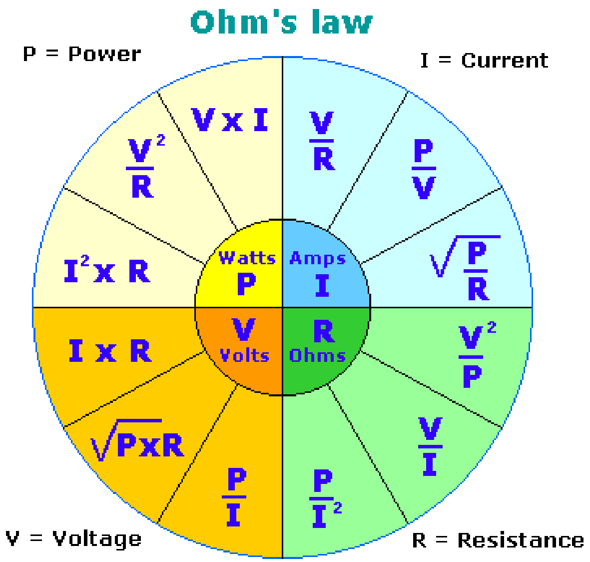
(E) Voltage is the difference in electrical potential between two points in a circuit. It's the push or pressure behind current flow through a circuit, and is measured in (V) volts.

(R) Resistance determines how much current will flow through a component. Resistors are used to control voltage and current levels. A very high resistance allows a small amount of current to flow. A very low resistance allows a large amount of current to flow. Resistance is measured in ohms.

(P) Power is the amount of current times the voltage level at a given point measured in wattage or watts.

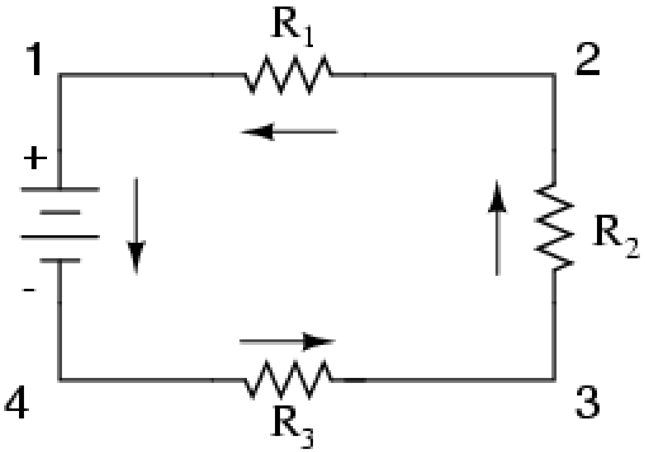
The 12 basic formulas for Ohm's Law :

1) Voltage = the Square Root of Power * Resistance
2) Voltage = Power / Current
3) Voltage = Current * Resistance
4) Resistance = Voltage / Current
5) Resistance = Power / Current squared
6) Resistance = Voltage squared / Power
7) Current = Voltage / Resistance
8) Current = the Square Root of Power / Resistance
9) Current = Power / Voltage
10) Power = Voltage * Current
11) Power = the Current squared * Resistance
12) Power = the Voltage squared / Resistance

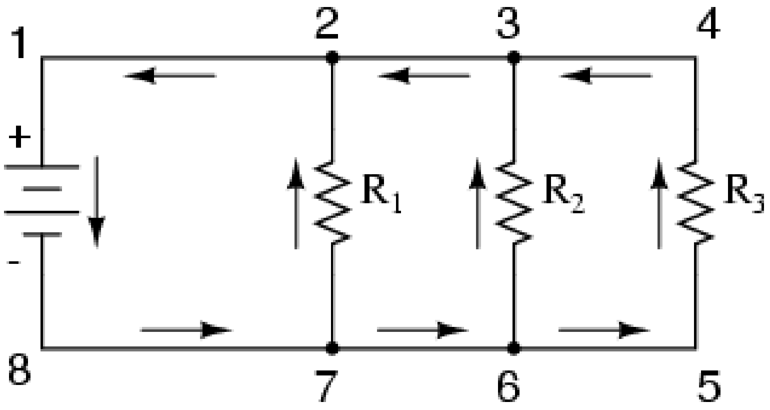


Series and parallel circuits

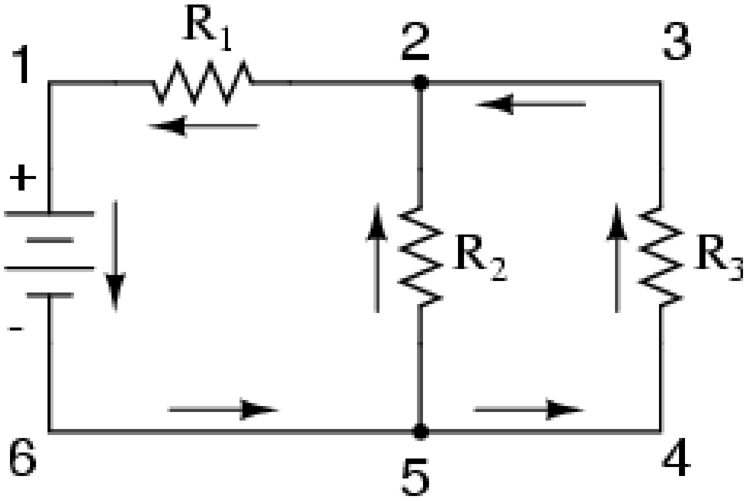
Series



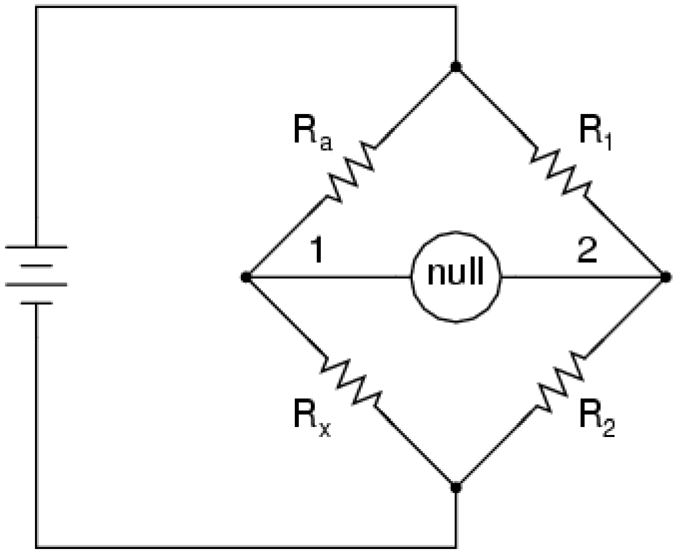
Parallel



Series-parallel

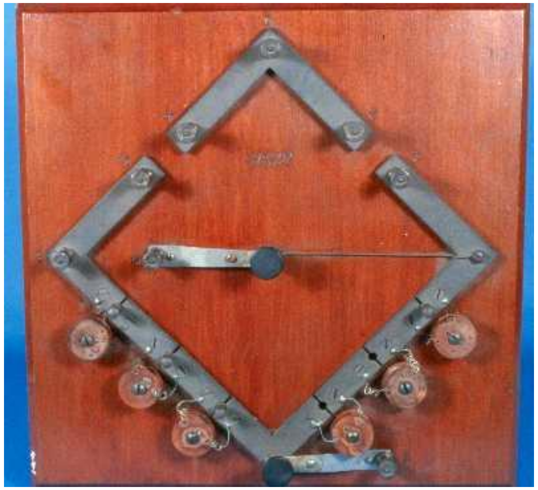


The standard bridge circuit, often called a *Wheatstone bridge*, looks something like this:



Bridge circuit is *balanced* when:

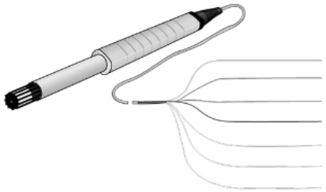
$$\frac{R_a}{R_x} = \frac{R_1}{R_2}$$



Invented by Charles Wheatstone (1802-1875), the *bridge* can be used to measure resistance by comparing unknown resistor against precision resistors of known value, much like a laboratory scale measures an unknown weight by comparing it against known standard weights.

Temperature measurements: Temperature can be measured using many kinds of sensors, including

- Thermometer (gas, liquid-in-glass)
- Electrical (variable resistors, thermocouple, etc.)



- Deformation
- Sonic thermometer

Table 1. Volumetric expansion at the room temperature of various materials

Alcohol	1.4 ^{o}C
Ice	0.7-0.9 ^{o}C
Water	0.21 ^{o}C
Mercury	0.18 ^{o}C
Glass	0.02-0.03 ^{o}C

A thermistor is a type of resistor whose resistance varies with temperature. Thermistors are widely used as inrush current limiters, temperature sensors, self-resetting overcurrent protectors, and self-regulating heating elements.
The material used in a thermistor is generally a ceramic or polymer. Thermistors typically achieve a higher precision within a limited temperature range [usually −90 °C to 130 °C].

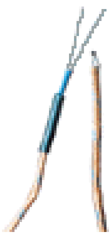
Assuming, as a first-order approximation, that the relationship between resistance and temperature is linear, then:

$$\Delta R = k\Delta T$$

Where ΔR = change in resistance ΔT = change in temperature k = first-order temperature coefficient of resistance

Thermocouples - An Introduction

(http://www.omega.com/prodinfo/thermocouples.html)



What is a thermocouple sensor?

A thermocouple is a sensor for measuring temperature. It consists of two dissimilar metals, joined together at one end. When the junction of the two metals is heated or cooled a voltage is produced that can be correlated back to the temperature. The thermocouple alloys are commonly available as wire.

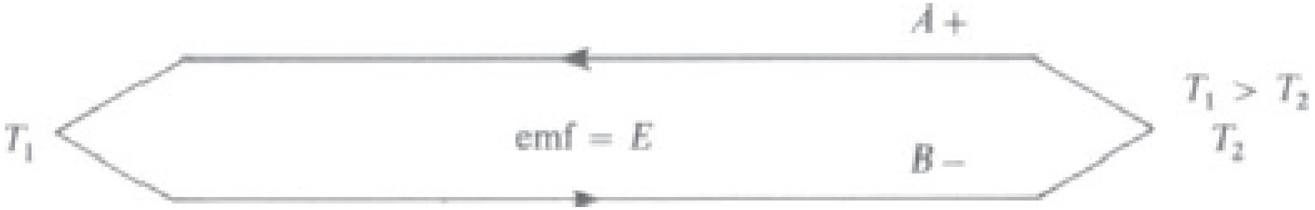


Figure 3.2. Seebeck effect.

The Seebeck effect is illustrated in Fig. 3.2, where junctions are formed between metals *A* and *B*. If one junction is at T_1 and the other junction is at a higher temperature T_2, a current will flow and will remain flowing as long as the temperature difference exists. The emf generated may be measured by inserting a voltmeter into either leg of the loop. A 0.56-mm copper–constantan thermocouple is shown in Fig. 3.3(a).

In 1821, Thomas Johann Seebeck fund a current that will flow in a circuit composed of 2 dissimilar materials when the 2 junctions were at different temperatures. The direction and the magnitudes of the electromotive force (emf) depend on temperature difference and materials used to construct TC.

$$d(\mathrm{emf}) = N_{a,b}\, dT$$

where $N_{a,b}$ is called the Seebeck coefficient. William Thompson (1851) concluded that “Current flow through a conductor will absorb or hibernate heat if a temperature gradient existed”.

Voltage–temperature relationship

The nonlinear relationship between the temperature difference (ΔT) and the output voltage (mV) of a thermocouple can be approximated by a polynomial:

$$\Delta T = \sum_{n=0}^{N} a_n v^n$$

The coefficients a_n are given for n from 0 to between 5 and 13 depending upon the metals. In some cases better accuracy is obtained with additional non-polynomial terms. A database of voltage as a function of temperature, and coefficients for computation of temperature from voltage and vice-versa for many types of thermocouple is available online.

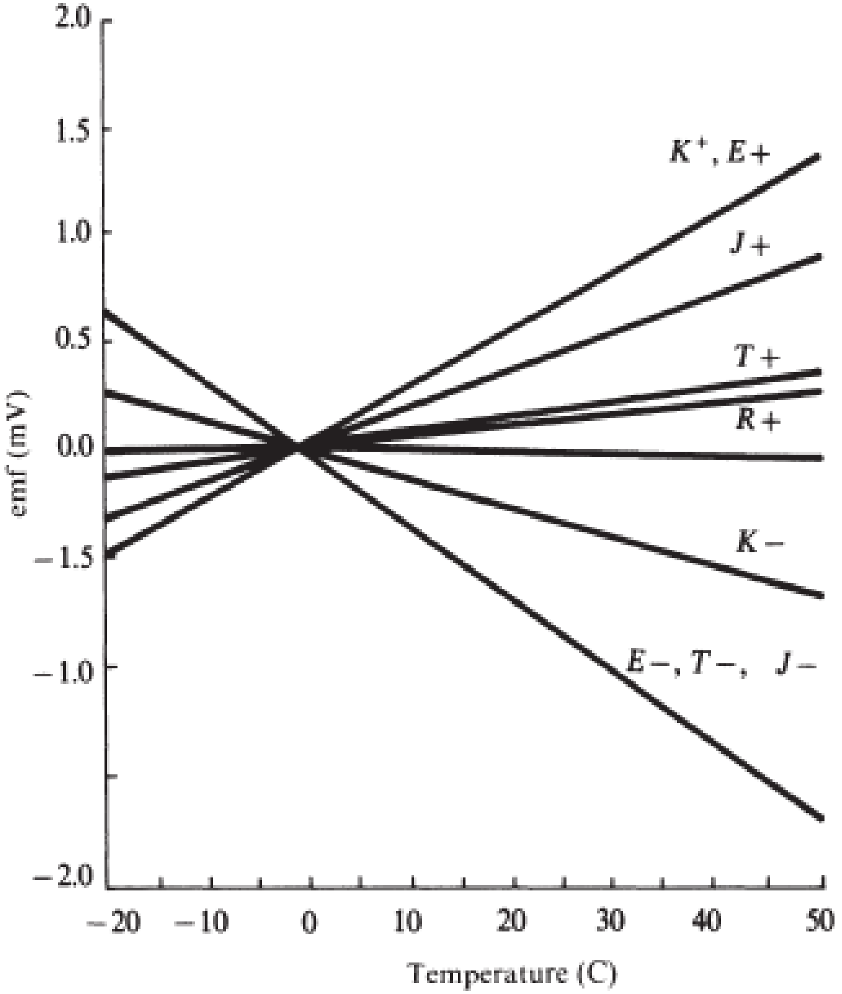


Figure 3.8. Emf versus temperature with respect to Platinum-67 for some common thermocouple materials. Platinum versus: chromel, *E*+, K^+; iron, *J*+; copper, *T*+; platinum–13% rhodium, *R*+; alumel, *K*−; constantan, *E*−, *T*−, *J*−. Data from National Bureau of Standards (Powell et al., 1974).

What are the different thermocouple types?

A thermocouple is available in different combinations of metals or calibrations. The four most common calibrations are J, K, T and E. There are high temperature calibrations R, S, C and GB. Each calibration has a different temperature range and environment, although the maximum temperature varies with the diameter of the wire used in the thermocouple.

Table 3.4. Seebeck coefficients of common thermocouple metals with respect to platinum-67. Metals are iron ($J+$), SAMA constantan ($J-$), copper ($T+$) and Adams constantan ($T-$). The sum of the two J components yields the Seebeck coefficient for iron–constantan (type J) thermocouples. The sum of the two T components yields the Seebeck coefficient for copper–constantan (type T) thermocouples (Powell et al., 1974).

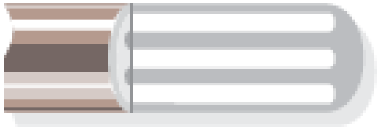
	Seebeck coefficients (μV °C^{-1})			
Temperature (°C)	$J+$	$J-$	$T+$	$T-$
0	17.9	32.5	5.9	32.9
50	17.9	34.9	7.8	35.0
100	17.2	37.2	9.4	37.4
150	16.0	39.2	10.6	39.5
200	14.6	40.9	11.9	41.3
250	13.1	42.4	13.1	42.7

Upper Temperature Limit in °C (°F) of Protected Bare Wire Thermocouples Vs. Wire Diameter

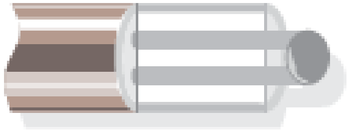
T/C Type	Wire Size						
	8 AWG 0.128"	14 AWG 0.064"	20 AWG 0.032"	24 AWG 0.020"	28 AWG 0.013"	30 AWG 0.010"	36 AWG 0.005"
J	760 (1400)	590 (1100)	480 (900)	370 (700)	370 (700)	320 (600)	315 (590)
K	1260 (2300)	1090 (2000)	980 (1800)	870 (1600)	870 (1600)	760 (1400)	590 (1100)
E	870 (1600)	650 (1200)	540 (1000)	430 (800)	430 (800)	370 (700)	320 (600)
T	370 (700)	370 (700)	260 (500)	200 (400)	200 (400)	150 (300)	
RX/SX	200 (400)	200 (400)	200 (400)	200 (400)	200 (400)	150 (300)	
N	1260 (2300)	1090 (2000)	980 (1800)	980 (1800)	980 (1800)	870 (1600)	
CX	472 (800)	472 (800)	472 (800)	472 (800)	472 (800)	400 (752)	

Common Thermocouple Junctions

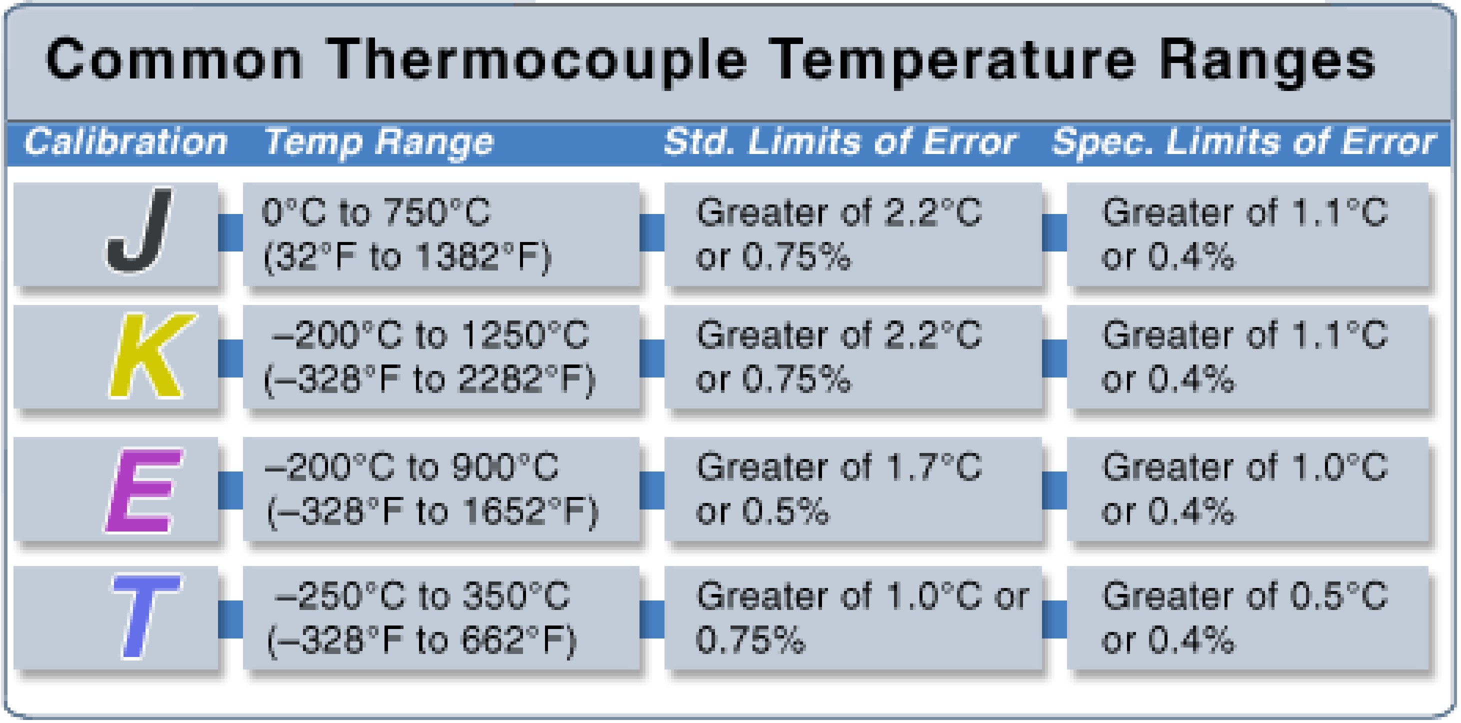
Grounded



Exposed



Ungrounded



Common Thermocouple Temperature Ranges

Calibration	Temp Range	Std. Limits of Error	Spec. Limits of Error
J	0°C to 750°C (32°F to 1382°F)	Greater of 2.2°C or 0.75%	Greater of 1.1°C or 0.4%
K	–200°C to 1250°C (–328°F to 2282°F)	Greater of 2.2°C or 0.75%	Greater of 1.1°C or 0.4%
E	–200°C to 900°C (–328°F to 1652°F)	Greater of 1.7°C or 0.5%	Greater of 1.0°C or 0.4%
T	–250°C to 350°C (–328°F to 662°F)	Greater of 1.0°C or 0.75%	Greater of 0.5°C or 0.4%

Thermocouple types

T: Copper-constantan (±0.8°C, -59 to 93 °C), red-blue

E: Chromel-constantan (±1.7°C, range 0 to 316 °C), pink-blue

K: Chromel-alumel (range -250 to 1260 °C)

J: Iron-constantan (low cost)

Thermocouple Laws

1. The low of homogeneous materials
2. The law of intermediate materials (permit soldering, using extension wires)
3. The law of successive or intermediate temperature

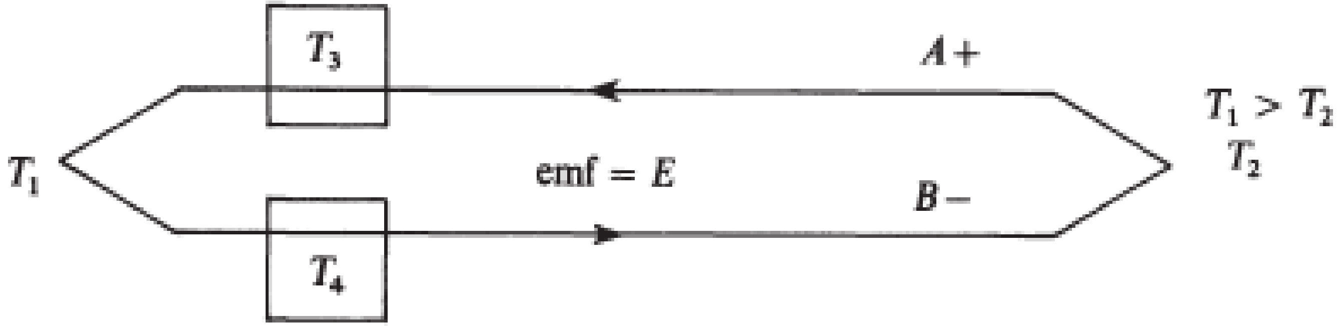


Figure 3.4. The Law of Homogenous Materials: T_3 and T_4 do not affect E.

As long as the metal of each wire in a thermocouple is homogeneous, the emf generated at the junction will not be affected by temperatures in the lead wire even though a temperature distribution exists along the lead wire, provided, of course, that the temperature is not conducted to the effective junction (Fig. 3.4).

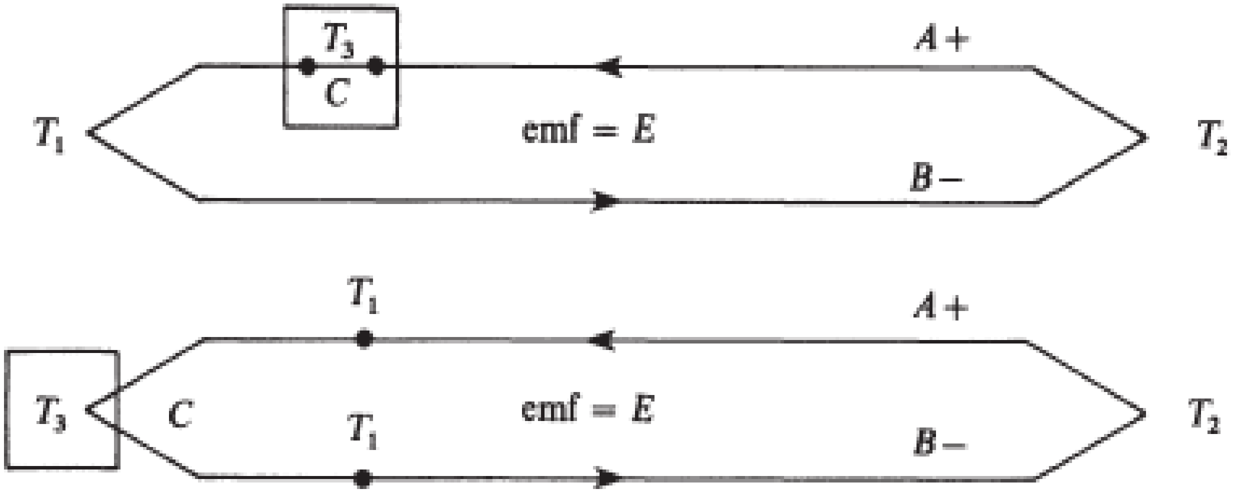


Figure 3.5. The Law of Intermediate Materials: third material, C, does not affect E.

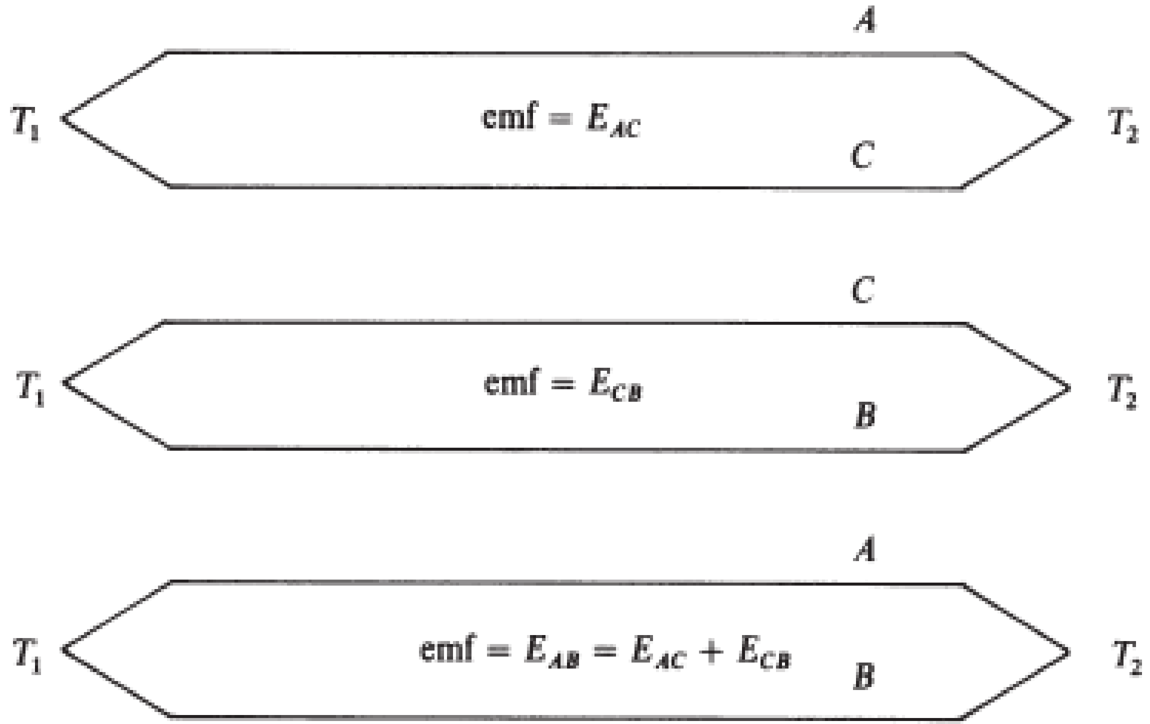


Figure 3.6. The Law of Intermediate Materials: emfs for materials are additive.

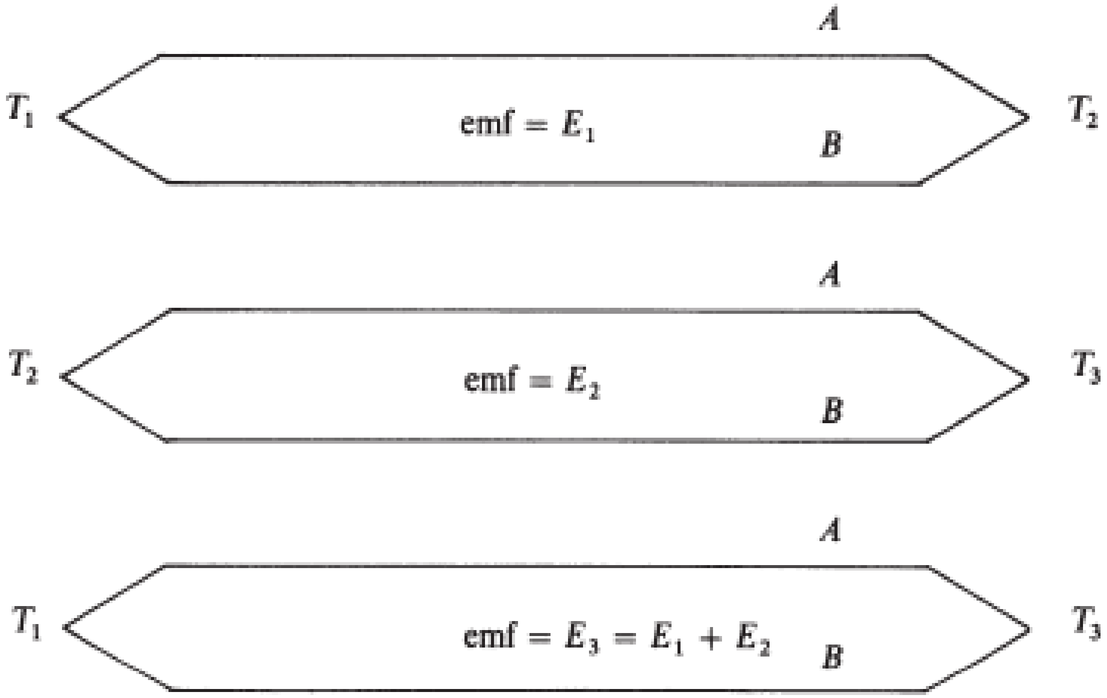


Figure 3.7. Law of Successive Temperatures: emfs for temperature are additive.

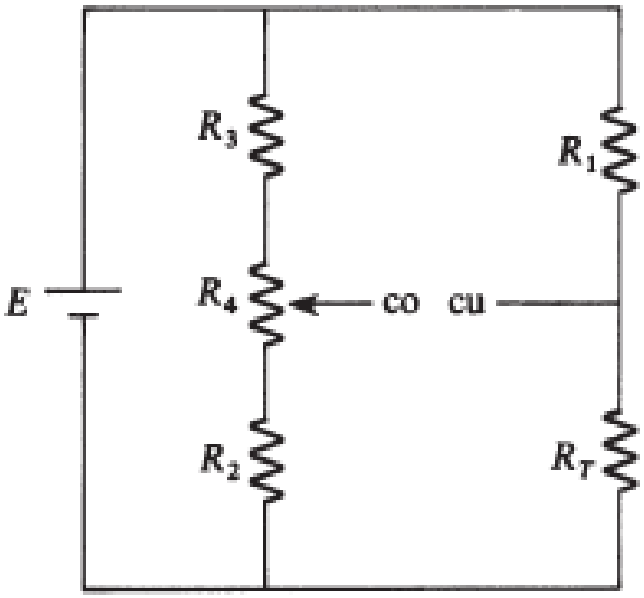


Figure 3.11. Thermocouple cold junction compensator. For copper–constantan: $R_1 = R_3 = 2\,000\ \Omega$; R_2 and $R_4 = 50\ \Omega$; R_4 is a 20-turn potentiometer; $R_T = 16.12\ \Omega$ at 20°C (approximately 7.47 m of 38-gauge copper wire); $E = 1.35$-V mercury battery; co = constantan connection; and cu = copper connection. For chromel–constantan: $R_1 = R_3 = 2\,000\ \Omega$; R_2 and $R_4 = 50\ \Omega$; R_4 is a 20-turn potentiometer; $R_T = 24.4\ \Omega$ at 20°C (approximately 11.31 m of 38-gauge copper wire); co and cu are copper connections; the chromel–copper and the constantan–copper connections must be at the same temperature; and $E = 1.35$-V mercury battery.

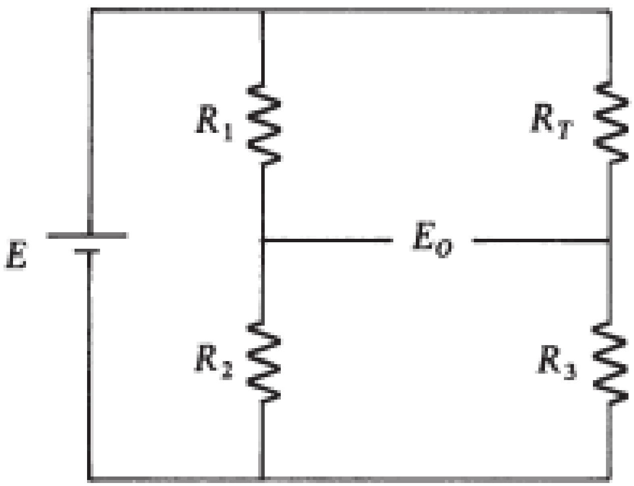
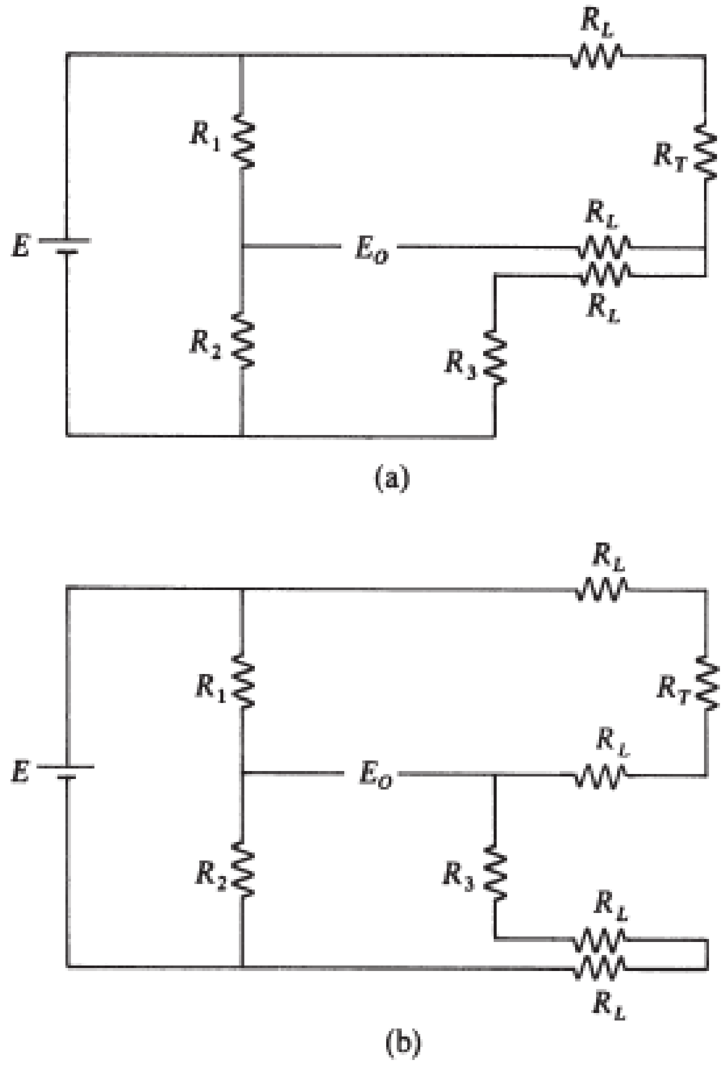


Figure 3.14. Wheatstone bridge. R_T is the temperature sensitive resistance element; R_1, R_2, and R_3 are fixed resistors; E is voltage applied and E_0 is voltage out.



(a)

(b)

Figure 3.17(a) and **3.17(b).** Multiwire Wheatstone bridge configurations. (a) Three-wire Wheatstone bridge where R_L is the leadwire resistance. (b) Four-wire Wheatstone bridge.

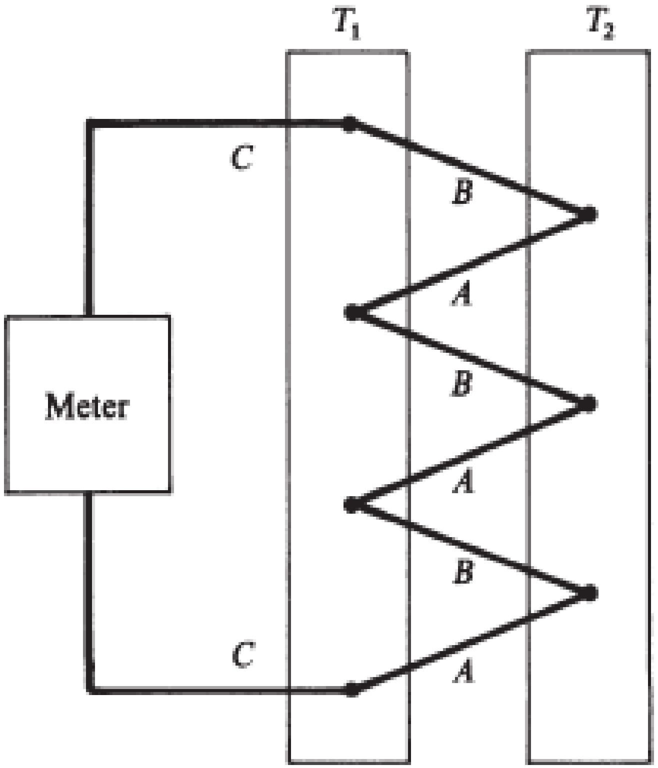


Figure 3.9. A multijunction thermopile. An example of a 3-junction thermopile made from materials *A* and *B*; *C* is leadwire.

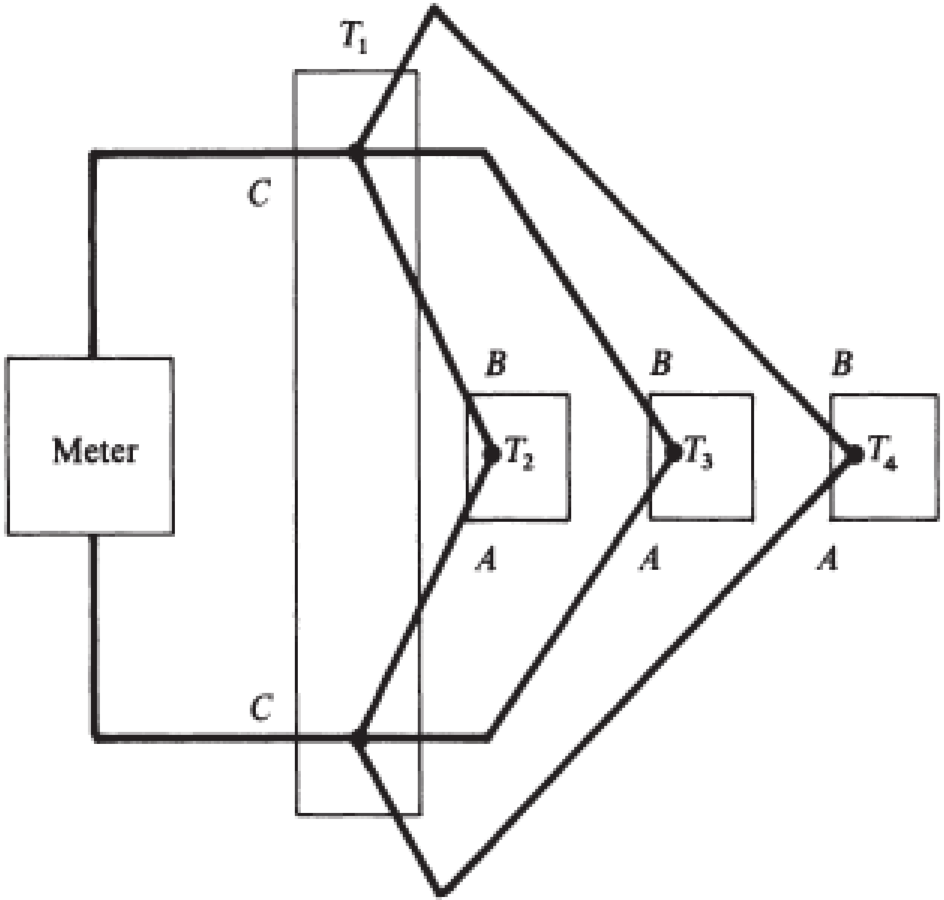


Figure 3.10. Parallel thermopile. An example of 3 thermocouples in parallel made from materials *A* and *B* ; *C* is lead material.

- A **thermopile** is an electronic device that converts thermal energy into electrical energy. It is composed of thermocouples connected usually in series or less commonly in parallel.

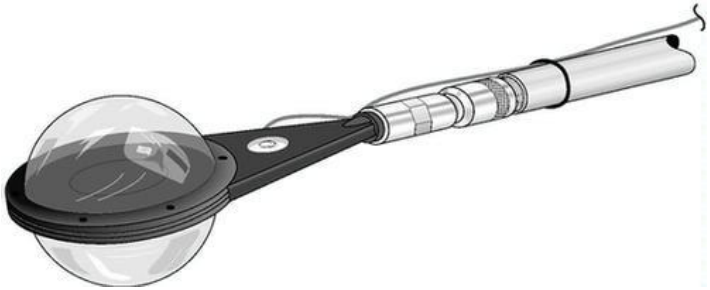
- Thermopiles do not measure the absolute temperature, but generate an output voltage proportional to a local temperature difference or temperature gradient.

- Thermopiles are the key component of the infrared thermometers that are widely used by medical professionals to measure body temperature via the ear.

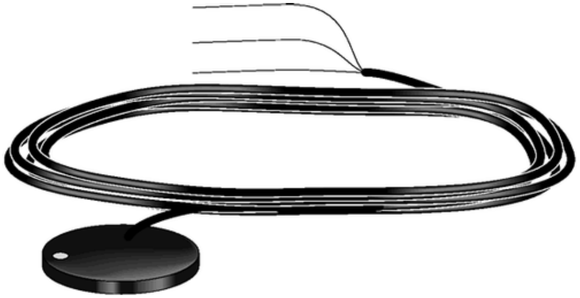
- They are also used widely in heat flux sensors (e.g. the Moll thermopile and Eppley pyrheliometer)

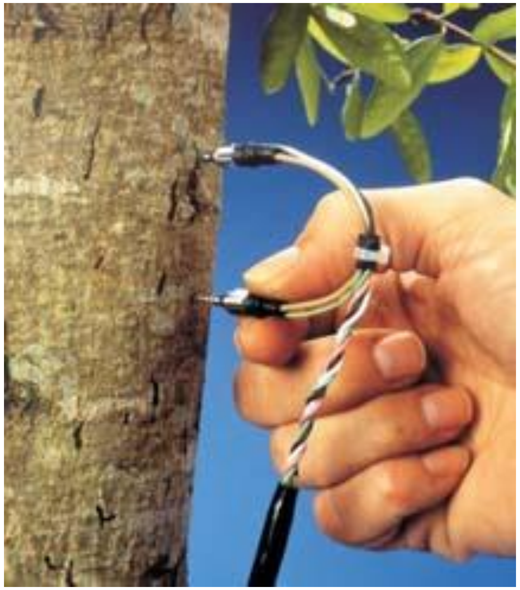
- Thermopiles have been used to generate electrical energy for various special purposes

Examples



- Vertical soil temperature
- Spatial variation of temperature
- Heat flux (HFT for soil heat flux) and net radiation (Q7 for Rn) of REBS
- Fine wire thermocouples and renew analysis
- Sapflow sensor





Some Key Points in Microclimatic Study

- Sensors need to be calibrated.
- A station needs to be maintained at a frequency of no more than 1 week.
- Time management is critical. Approximately 1/3 of your time needs to be allocated for preparation, maintenance, and data analysis.
- Skills on trouble-shooting are more important than installation.
- Hands on – learn from making mistakes