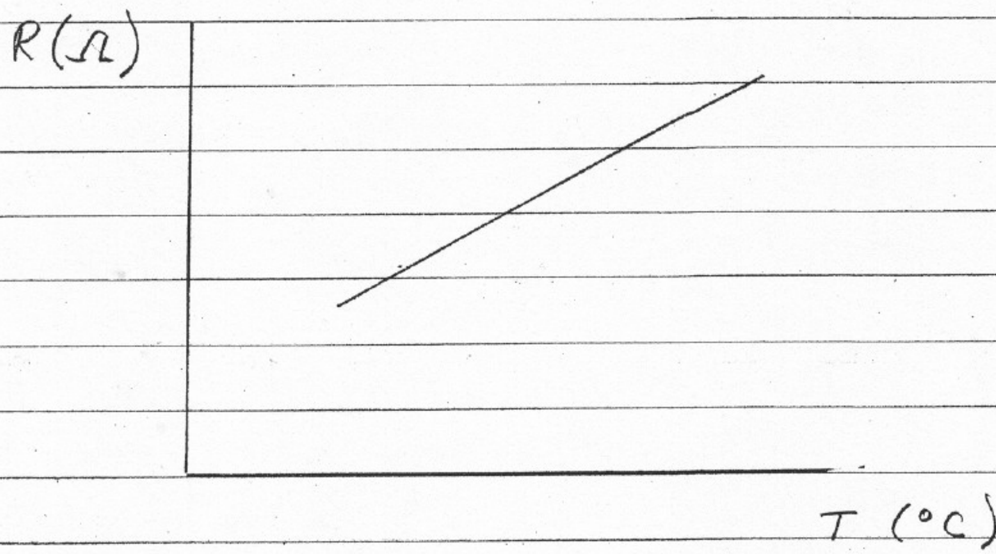
RTD - Resistance Temperature Detector

Thermistor - Therm~~al~~ ~~Res~~istor

The electrical resistance of these sensors varies with temperature

$$R = R(T)$$

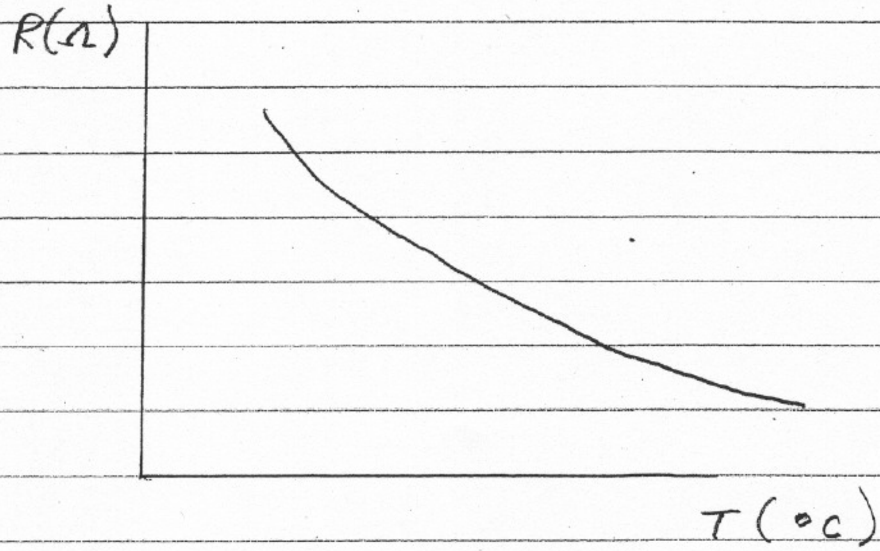
RTD - constructed from metal wire



R increases with increasing T

function R(T) is linear

Thermistors - constructed from temperature sensitive ceramic semiconductors



R decreases with increasing T

function R(T) is nonlinear

RTD

coiled wire used to eliminate mechanical strain; mechanical strain changes the resistance of the wire ⟹ strain gage

Linear Model

$$R(T) = R_o\left[1 + \alpha(T - T_o)\right]$$

$$\frac{R}{R_o} = 1 + \alpha(T - T_o) \qquad (1)$$

T_o - reference temperature (°c)

R_o - reference resistance (Ω)

α - thermal coefficient of resistivity (1/

Use

Need to measure electrical resistance and then determine T from a calibration plot or equation (1)

Accuracy

Uncertainty in temperature measurement ± 0.005°c ; probably 1 σ bound.

RTD Resistance Measurement

1. Conventional ohmmeters

small current flow through RTD causes

I^2R heating of RTD; called loading error

2. Wheatstone bridge

no current through RTD; no loading error

accurate resistance measurement

resistance of leads connecting RTD can

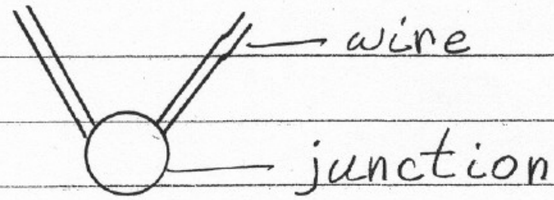
cause large errors

How can you measure time varying

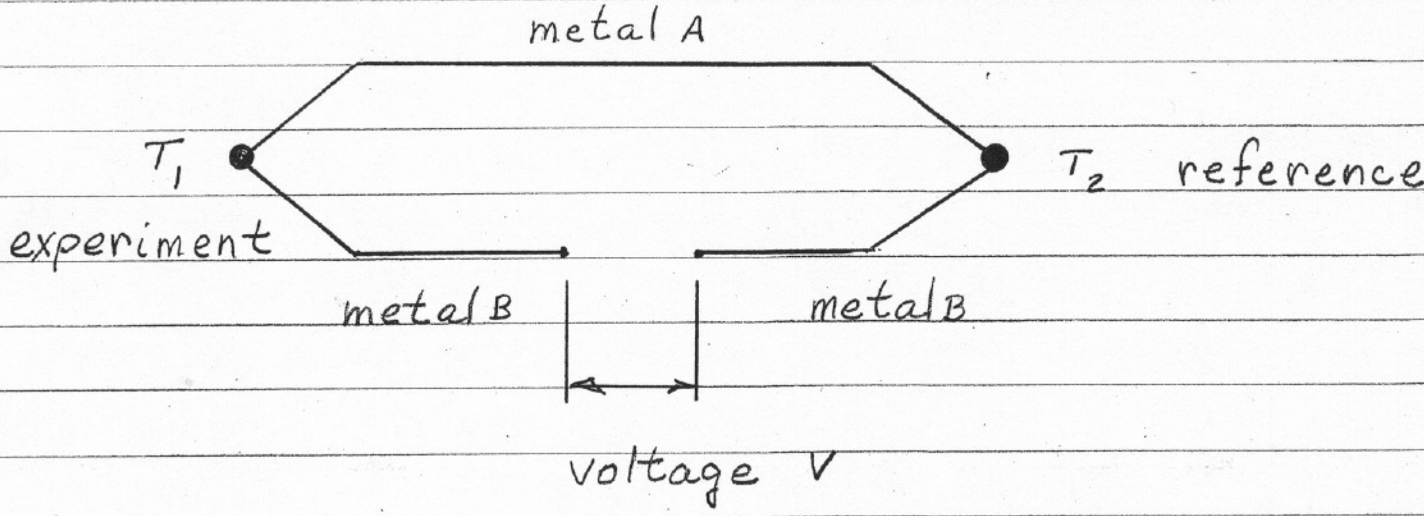
temperatures with an RTD?

Thermocouple

consists of two electrical conductors made of different metals with one end of each welde[d] together.



Thermocouple Circuit



$T_1 \neq T_2 \Rightarrow$ open-circuit voltage V

$$V = V(T_1 - T_2 ; A \& B)$$

Thermoelectric Phenomena result from the simultaneous flow of heat and electrical

current in the an electrical conductor
Theoretial basis involves irreversible
thermodynamics

THERMOCOUPLES

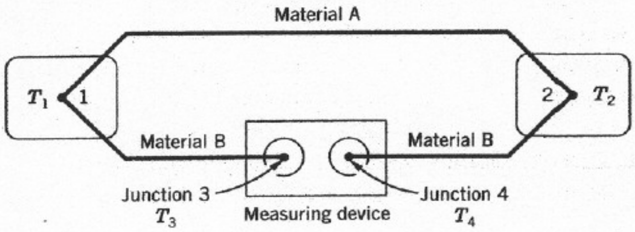


Figure 8.14 Typical thermocouple measuring circuit.

Seebeck Effect

A potential difference, or emf, is produdu
in an open thermocouple circuit when a
temperature difference is applied across
the junctions.

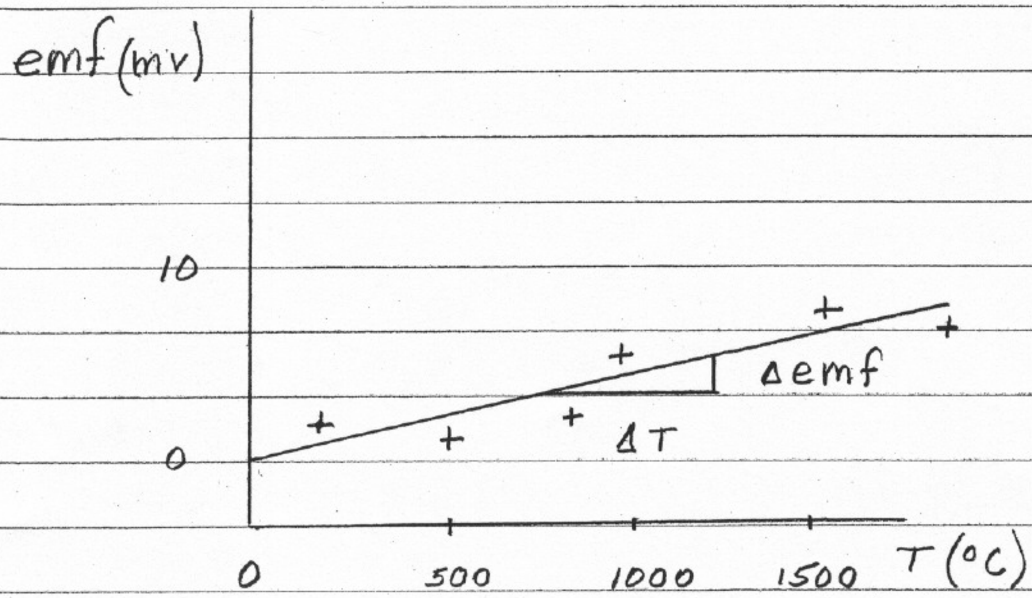
open circuit means no current flow

There is a fixed functional relationship
between the emf and the temperatures
T_1 and T_2. See Figure 8.13.

Static Calibration generates the curve

Seebeck Coefficient

$$\alpha_{AB} = \left.\frac{\partial(emf)}{\partial T}\right|_{\text{open circuit}} = \frac{\Delta emf}{\Delta T}$$



We need to measure the emf, voltage, across the terminals labeled junction 3 and junction with minimal current flowing through the circuit. Use a high impedence voltmeter.

A current will introduce other thermoelectric effects that change the calibration.

Dynamic Calibration

Use the 1st-order linear model discussed in the last lecture

$$\tau \frac{dT}{dt} + T = C\,U(t)$$

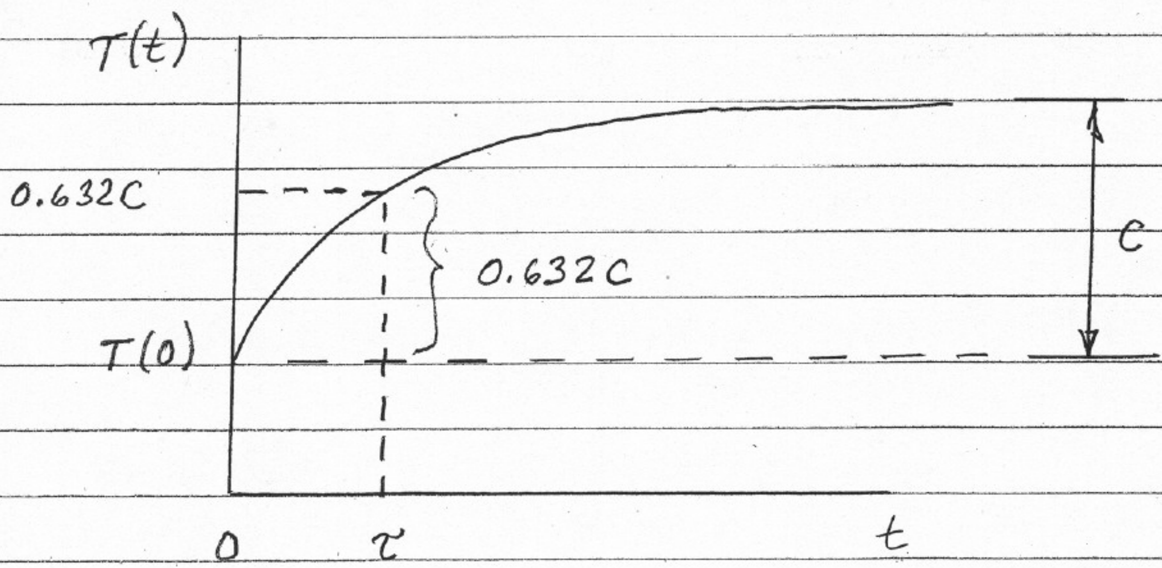
solution

$$T(t) = T(0) + C\left(1 - e^{-t/\tau}\right)$$

$T(0)$ - initial temperature

C - change in ambient temperature

τ - time constant



Suppose $t = \tau$

$$\frac{T(t) - T(0)}{c} = 1 - e^{-1} = 0.632$$

Fundamental Thermocouple Laws

1. Law of Homogeneous Materials

   You need two different metal wires to make a thermocouple.

2. Law of Intermediate Materials

   If two junctions of a thermocouple circu are at the same temperature, the resultant emf will not change from the open circuit emf

3. Law of Intemediate Temperatures

If T_1 & $T_2 \Longrightarrow emf_1$

T_2 & $T_3 \Longrightarrow emf_2$

Then T_1 & $T_3 \Longrightarrow emf_1 + emf_2$

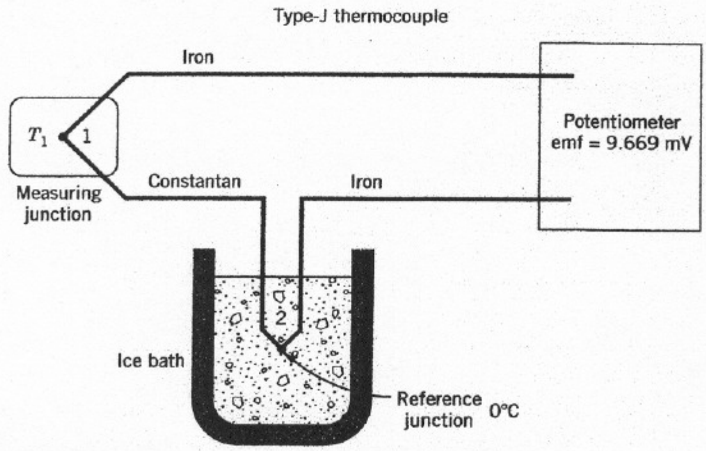


Figure 8.19 Thermocouple circuit for Example 8.6.

an ice-point bath. The voltage output is measured with a potentiometer and is found to be 9.669 mV. What is T_1?

KNOWN

A thermocouple circuit having one junction at 0°C and a second junction at an unknown temperature. The circuit produces an emf of 9.669 mV.

FIND

The temperature T_1.

ASSUMPTION

Thermocouple follows NIST standard.

SOLUTION

Standard thermocouple tables such as Table 8.6 are referenced to 0°C. The temperature of the reference junction for this case is 0°C. Therefore, the temperature corresponding to an output voltage may simply be determined from Table 8.6, in this case as 180°C.

COMMENT

Because of the law of intermediate metals, the junctions formed at the potentiometer do not affect the voltage measured for the thermocouple circuit, and the voltage output reflects accurately the temperature difference between junctions 1 and 2.

EXAMPLE 8.7

Suppose the thermocouple circuit in the previous example (Example 8.6) now has junction 2 maintained at a temperature of 30°C and produces an output voltage of 8.132 mV. What temperature is sensed by the measuring junction?

KNOWN

T_2 is 30°C, and the output emf is 8.132 mV.

ASSUMPTION

Thermocouple follows NIST standard.

FIND

The temperature of the measuring junction.

SOLUTION

By the law of intermediate temperatures the output emf for a thermocouple circuit having two junctions, one at 0°C and the other at T_1, would be the sum of the emfs for a thermocouple circuit between 0 and 30°C and between 30°C and T_1. Thus,

$$\text{emf}_{0-30} + \text{emf}_{30-T_1} = \text{emf}_{0-T_1}$$

This relationship allows the voltage reading from the nonstandard reference temperature to be converted to a 0°C reference temperature by adding $\text{emf}_{0-30} = 1.537$ to the existing reading. This results in an equivalent output voltage, referenced to 0°C as

$$1.537 + 8.132 = 9.669 \text{ mV}$$

Clearly, this thermocouple is sensing the same temperature as in the previous example, 180°C. This value is determined from Table 8.6.

COMMENT

Note that the effect of raising the reference junction temperature is to lower the output voltage of the thermocouple circuit. Negative values of voltage, as compared with the polarity listed in Table 8.4, indicate that the measured temperature is less than the reference junction temperature.