Voluntary task:

By measuring at 0°C and 100°C, establish R_0 *and* ***Alpha*** *for the given platinum thermometer. Verify with theoretical values and check with the boundaries for Class A/Class B sensor. Let us define error bounds of set temperature as ±0.1°C.*

Verification / calibration of Platinum thermometer – 2 point method

We know that the temperature/resistance relationships used with Platinum thermometers are as follows:

- for the range -200 °C to 0 °C:

$$R_t = R_0\ [1 + At + Bt^2 + C(t - 100^{\circ}C)t^3] \quad (1)$$

- for the range 0 °C to 850 °C:

$$R_t = R_0\ [1 + At + Bt^2) \quad (2)$$

Where

R_0= 100 Ω or 1000Ω

A = 3.9083 x 10^{-3} °C $^{-1}$
B = -5.775 x 10^{-7} °C $^{-2}$
C = -4.183 x 10^{-12} °C $^{-4}$

Calculating the inverse function (resistance to temperature) from Eq. 1 or 2 is not straightforward (two roots for positive temperatures, more complicated for negative temperatures). In the international temperature scale ITS-90, the equation gets *even more complicated* with 10++ non-linear coefficients depending on covered temperature range.

Also, to obtain best calibrating precision, the **calibration of the thermometer** has to rely on fixed points on the temperature scale (triple point of water at 0.01°C, melting point of Gallium and other metrological points for higher temperatures). For details, see next page.

For **practical use of resistance thermometers** we can derive a more simple formula with a **single coefficient α**, which is widely used in industry (see DIN/ IEC 751):

$$\boldsymbol{R_t = R_0\ (1 + \alpha\ t)} \quad (3)$$

If we define **α** as **α**= (R_{100} - R_0)/100R_0, where R_{100} is the resistance at 100 °C and R_0 is the resistance at 0 °C, we can achieve both points with reasonable uncertainty (due e.g. to atmospheric pressure, water purity, mixing) even in our laboratory. For thermometers with the coefficients A, B, C, see above, the exact value (established from 0/100°C) is **α** = **0.00385055 °C** $^{-1}$.

By obeying the higher orders, of course we introduce errors. Also the purity of the Platinum and precision of achieving R_0 by manufacturing has an effect on the thermometer precision. However, for the “A-class” industrial Platinum thermometer, the error bounds are only ±0.35°C between -100°C and 100°C, see table below.

Tolerances, Pt100 and Pt1000
The tolerance values of resistance thermometers are classified as follows:

Tolerance class	Tolerance (°C)
A	0.15 + 0.002 |t|*
B	0.3 + 0.005 |t|

* \|t\| = modulus of temperature in degrees Celsius without regard to sign.

Temperature (°C)	Tolerance Class A (± °C)	Class A (± Ω)	Class B (± °C)	Class B (± Ω)
-200	0.55	0.24	1.3	0.56
-100	0.35	0.14	0.8	0.32
0	0.15	0.06	0.3	0.12
100	0.35	0.13	0.8	0.30
200	0.55	0.20	1.3	0.48
300	0.75	0.27	1.8	0.64
400	0.95	0.33	2.3	0.79
500	1.15	0.38	2.8	0.93
600	1.35	0.43	3.3	1.06
650	1.45	0.46	3.6	1.13
700	-	-	3.8	1.17
800	-	-	4.3	1.28
850	-	-	4.6	1.34

The following is cited from the Temperature Handbook, LabFacility, available online at www.labfacility.co.uk.

Please note that even after the re-definition of the Kelvin by fixing the Boltzman constant in the new SI, only the associated temperatures of the fixed points might change slightly but not the fixed points by themselves, which are realized and maintained in primary laboratories with low uncertainty.

See also the description of available uncertainties at the Czech Metrology Institute:
https://www.cmi.cz/node/412

9.4.2. Fixed Temperature Points

Materials exist in different states (phases), liquid, solid or gas according to their temperature. At certain specific temperatures, two or three phases can occur simultaneously. In water for example, the three phases can exist together at the **triple point** (0.01°C). Triple points are unusual and most materials exhibit only two coincident phases.

Other fixed points are the freezing points of pure metals. As a molten metal is cooled, the melt begins to solidify at a certain temperature depending on the particular metal. The change from liquid to solid does not occur suddenly and, during this change of phase the temperature remains constant until the metal has entirely solidified. This freezing point temperature value depends only on the degree of purity of the metal; knowledge of this temperature and the facility to achieve it provides a highly accurate and absolutely reproducible temperature reference.

9.4.3. International Temperature Scale ITS-90

The temperature values of the fixed points are determined with devices suitable for measuring thermodynamic temperatures such as gas thermometers. Discussion between the various National laboratories has resulted in the official adoption of certain fixed points internationally as **primary temperatures**. Intermediate values on the resulting temperature scale are defined by interpolation. The scale thus established has practical application in science and industry using commercially available calibrated, high precision platinum resistance thermometers.

The development of the more accurate ITS-90 which replaces the IPTS-68 defines the following fixed points:

Equilibrium state	
Triple point of hydrogen	-259.3467°C
Boiling point of hydrogen at a pressure of 33321.3 Pa	-256.115°C
Boiling point of hydrogen at a pressure of 101292 Pa	-252.88°C
Triple point of neon	-248.5939°C
Triple point of oxygen	-218.7916°C
Triple point of argon	-189.3442°C
Triple point of mercury	-38.8344°C
Triple point of water	0.01°C
Melting point of gallium	29.7646°C
Freezing point of indium	156.5985°C
Freezing point of tin	231.928°C
Freezing point of zinc	419.527°C
Freezing point of aluminium	660.323°C
Freezing point of silver	961.78°C
Freezing point of gold	1064.18°C
Freezing point of copper	1084.62°C

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