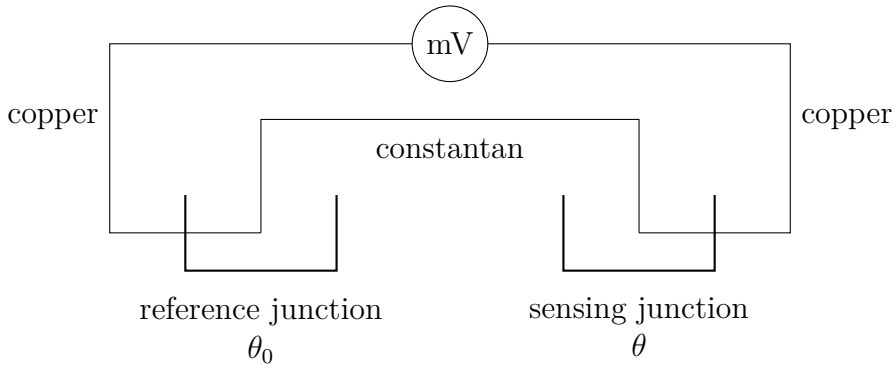
Planning and calibrating a thermocouple

Name: _____ Class: _____ Date: _____

Aim Plan and carry out a calibration, then assess an unknown temperature. Allow 70–90 minutes.

Model A **thermocouple** uses two different metals. Over a limited range, $V = a(\theta - \theta_0) + b$. θ is the sensing-junction temperature and θ_0 is the reference-junction temperature. Determine a and b without forcing the graph through zero.

Apparatus Two copper wires and one constantan wire, sensitive millivoltmeter, digital or non-mercury thermometer, two water baths/beakers, warm water, stirrer and clamp. Teacher supplies the unknown warm-water bath.



Safety Use teacher-provided warm water and stable containers. Keep the meter dry. Do not heat a wire in a flame: extrapolating a water calibration to a flame temperature is unreliable and unnecessary.

1 Plan before handling apparatus

Write a method to obtain at least six well-spread temperature differences and repeat readings. Explain how you will form secure junctions, keep θ_0 stable, measure both bath temperatures and wait for thermal equilibrium. Include a zero-difference check and meter polarity.

State two controls, a usable temperature range and precautions for hot water and sharp wire ends.

Teacher method/safety check: _____ Date: _____.

2 Carry out and record

After approval, form secure copper–constantan junctions. Keep both copper-to-meter connections together at the same room temperature. Place the reference junction in a stable room-temperature bath. Stir each bath gently; let the junction and thermometer settle before reading.

Meter resolution: _____ mV Thermometer resolution: _____ °C.

θ/°C	θ_0/°C	$\Delta\theta$/K	V_1/mV	V_2/mV	$\bar{V}$/mV

Zero check With both junctions at the same temperature, measured $V =$ _____ mV.

Unknown bath $V_u =$ _____ mV $\theta_{0,u} =$ _____ °C.

Record the unknown thermometer reading only after predicting its temperature: _____ °C.

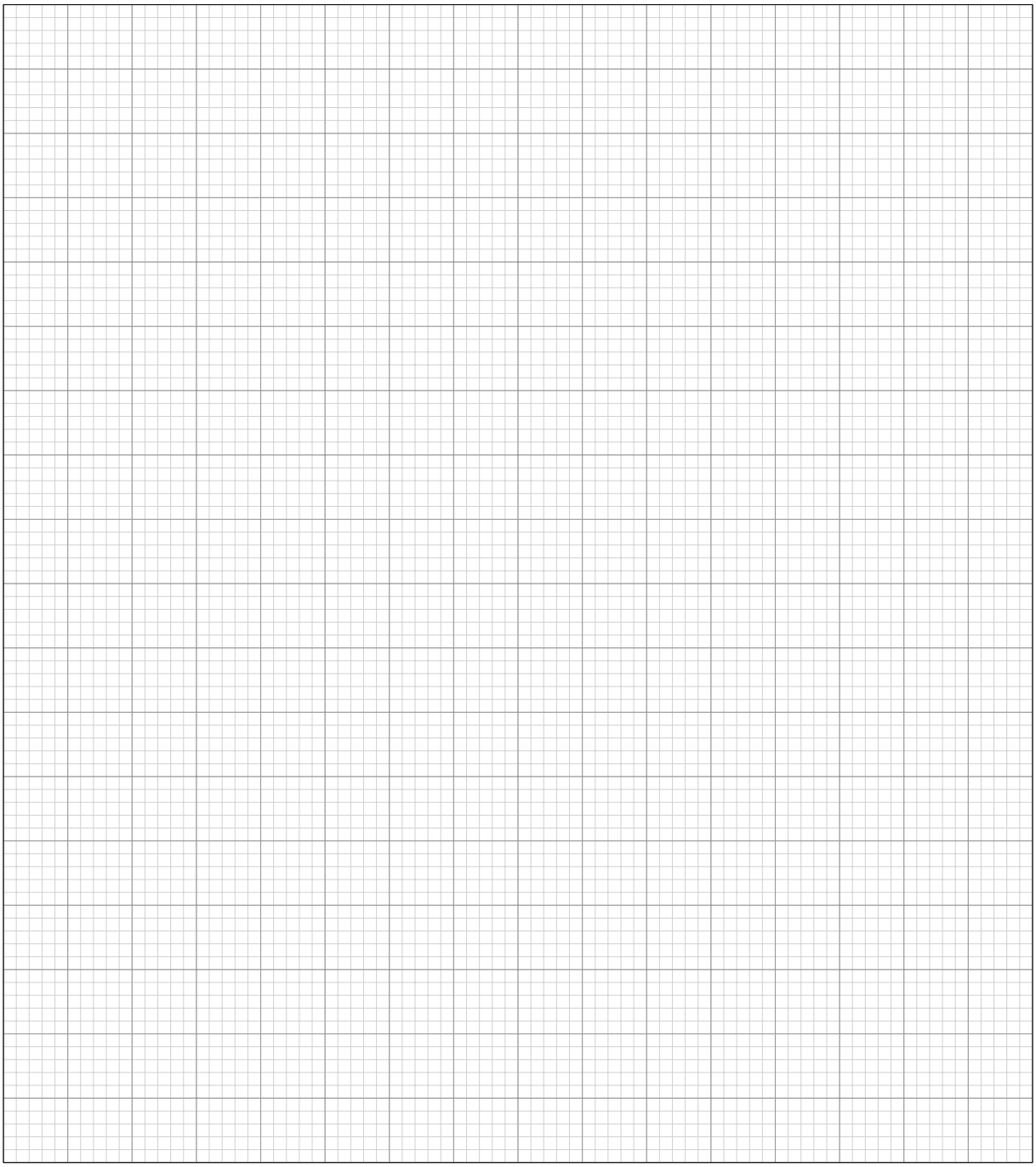
Uncertainty Estimate ΔV and $\Delta(\Delta\theta)$. A temperature difference includes uncertainty in both temperatures.

Method changes Describe any revision to your plan and why it was needed.

Processing check (synthetic data) For $V_u = 1.220$ mV and $\theta_{0,u} = 20.0\,°\text{C}$, two acceptable fits are $(a, b) = (0.0390, 0.0300)$ and $(0.0410, 0.0100)$ in mV K^{-1} and mV. Calculate both predicted temperatures, keeping each slope with its own intercept.

3 Calibration graph

Plot $\bar{V}$ against $\Delta\theta = \theta - \theta_0$. Include uncertainty bars. Fit a line without forcing zero; use extreme acceptable lines to estimate the range of possible calibrations.



Choose scales and label both axes with quantities and units. Mark a large gradient triangle on the best-fit line where appropriate.

4 Analyse and evaluate

1. Find a and b, with units. Does your zero-difference check agree with the fitted intercept? Explain whether a non-zero b is likely to be a physical thermocouple e.m.f. or an offset in the measurement.

2. Calculate $\theta_u = \theta_{0,u} + (V_u - b)/a$. Use extreme acceptable calibrations to estimate a temperature interval. Compare with the independent thermometer reading and its uncertainty.

3. Explain why θ_0 must be recorded during calibration and unknown measurement. Identify two limitations, such as changing reference temperature, poor junction contact or thermal lag, and give matched improvements.

4. Why would extrapolating this calibration to a flame be weak evidence? Consider non-linearity, range, wire oxidation and equilibrium. State the temperature range over which your calibration is supported.

Before you leave Return the apparatus, clear the bench and submit your recorded data.