Specific heat capacity with a cooling correction

Name: _____ Class: _____ Date: _____

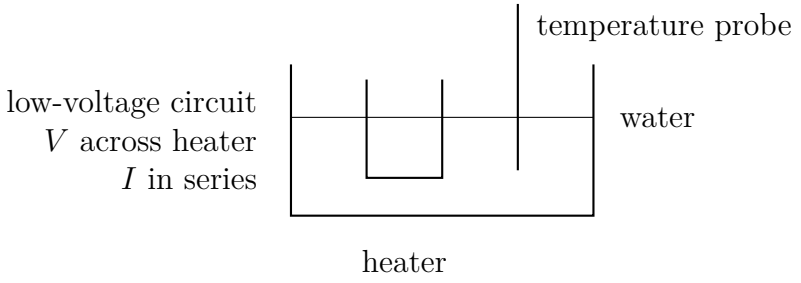
Aim Use heating and cooling rates to correct for heat loss. Allow 80–100 minutes, including cooling.

Model At the same water temperature, let $S_H = d\theta/dt > 0$ during heating and $S_C = -d\theta/dt > 0$ during cooling. If heat loss is the same in both stages,

$$VI = (m_w c_w + m_g c_g)(S_H + S_C), \quad c_g = 840\,\mathrm{J\,kg^{-1}K^{-1}}.$$

The **specific heat capacity** c_w is the target; this model neglects the heater and probe heat capacities.

Apparatus Teacher-approved immersion heater or suitably rated 15 Ω resistor, current-limited low-voltage d.c. supply, ammeter, voltmeter, switch, glass beaker, about 75 $\mathrm{cm^3}$ water, thermometer/probe, stirrer, balance and stopwatch.



Safety Switch off before touching the heater or changing connections. Keep it submerged when powered. Keep plugs and supply dry. Hot water can scald; use a stable beaker and no mains heater. Never exceed component power ratings.

1 Measure a continuous temperature record

1. Weigh dry beaker m_g, then beaker plus water m_t; $m_w = m_t - m_g$. Record room temperature. Position heater and probe without contact with glass.
2. Start heating and timing together. Record V, I and temperature every 30–60 s, chosen by a pilot. Stir gently and consistently throughout.
3. At about 15 °C above the start, switch off. Mark the exact switching time. Keep the same clock, stirring, water and apparatus positions.
4. Continue recording until at least 6 °C below the peak. Do not remove the heater. Record power readings during heating to test whether power stayed constant.

Processing check (synthetic data) For $P = 9.60$ W, $S_H = 0.0200$, $S_C = 0.00400\,\mathrm{K\,s^{-1}}$, $m_w = 0.0750$ kg and $m_g = 0.100$ kg, calculate corrected c_w. Recalculate ignoring cooling and compare.

2 Record measurements

$m_g =$ _____ kg $m_t =$ _____ kg $m_w =$ _____ kg.

Room temperature: _____ Temperature resolution: _____.

t/s	θ/ °C	V/V	I/A	Heating/cooling

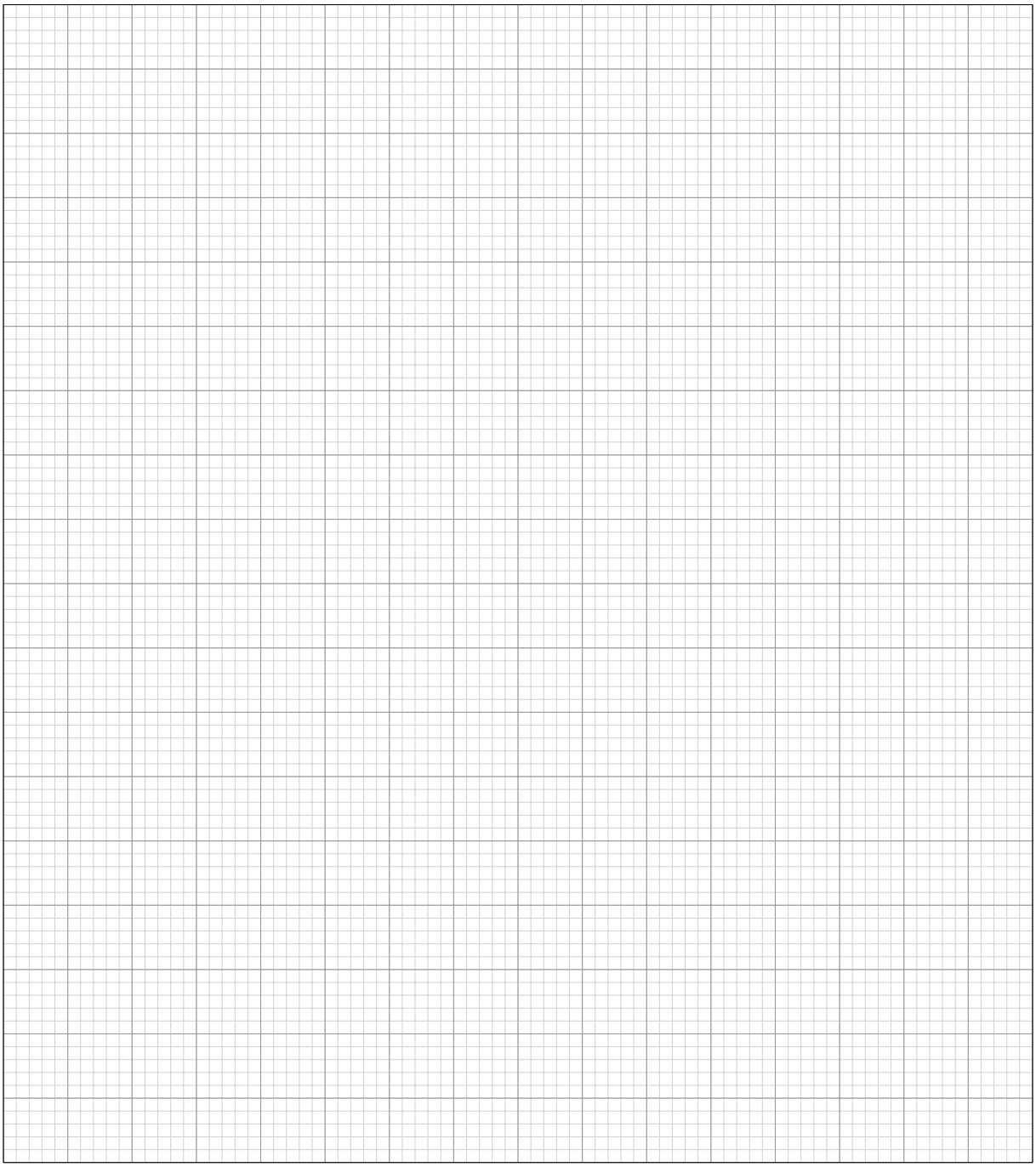
Record Switching time: _____ s. Peak temperature: _____ °C.

Selected common temperature θ_1 (about 4 °C below peak): _____ °C.

Note any evaporation, power variation or temperature lag.

3 Graph

Plot θ against the continuous time t. Draw smooth heating and cooling curves. At the same θ_1, draw a tangent to each curve and large triangles for their gradients.



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

4 Analyse, evaluate and plan

1. Calculate S_H and the positive magnitude S_C in K s^{-1}. Rearrange to $c_w = [VI/(S_H + S_C) - m_g c_g]/m_w$. Show substitutions. Compare with 4.18×10^3 J kg^{-1} K^{-1}, allowing for limitations.

2. Explain why the two tangents must be taken at the same temperature. Predict the direction of error if cooling losses are ignored. Explain the likely effect of neglected heater heat capacity.

3. Estimate uncertainty by drawing plausible alternative tangents. Identify two limitations with matched improvements; consider lag, uneven water temperature, evaporation and changing power.

4. Plan a separate test of $\theta - \theta_R = (\theta_0 - \theta_R)e^{-\alpha t}$. Specify readings, controls, safety and a graph whose gradient determines α. State why room temperature must be measured and small temperature differences are unreliable.

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