REAL-LIFE PHYSICS

Electricity and Matter

Teacher guide

For the National 5 Physics workbook



C. Blewis

Blewis LEARNING

Using the workbooks

The National 5 Physics workbook for **Electricity and Properties of Matter** has eight topics. Every topic has learning pages, a practical the learner plans and evaluates (with uncertainties), a brain break and an exam-style check-up.

PRACTICALS

Learners plan each investigation (variables, prediction, kit, risk, method), take repeat readings, work out averages, draw graphs with their own scales, and write conclusions and evaluations.

PRACTICAL SAFETY

Every practical has a Stay safe table and a teacher note with hazards, adapted versions and common problems. The Stay safe tables and these notes are a starting point, not a complete risk assessment: the teacher or school must risk assess every practical for their own learners, room and kit before use, following their employer's policies and national guidance (in Scotland, SSERC). Always check learners' care plans and medical information. Activities with flames or microbes are teacher demonstrations, with example results provided.

NO LAB, NO KIT, OR A LEARNER ABSENT

Each practical includes example results so learners can still complete the results, graph, conclusion and evaluation.

EVIDENCE

The practicals give evidence for the experiment and investigation outcome; the learn pages and check-ups give evidence for knowledge and problem solving. The skills tracker at the back of each workbook can be signed off as you go. Always check the latest course documents and your centre's arrangements.

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TEACHER NOTES

Practical 1: Current and charge

Time	One 50-minute lesson in pairs. Five currents × three 60 s runs takes about 20 minutes of running time.
Kit per group	Low-voltage d.c. supply, rheostat (variable resistor) rated for 1 A, ammeter (0–1 A), coulomb meter (or a current sensor with a data logger that integrates current), stopwatch, leads.
Prep	Check coulomb meters reset and read in coulombs. If none are available, a data logger can record current every 0.1 s and calculate charge; learners then compare with I × t.
Expected results	Charge proportional to current: about 6 C at 0.10 A up to about 30 C at 0.50 A in 60 s. Gradient of Q against I ≈ 60 s.
Level	N5 plans, repeats, calculates means and random uncertainties, draws a line graph with a line of best fit, uses the gradient, evaluates.

Safety and inclusion

- Low voltage only. Keep currents at 0.5 A or less; rheostat coils can get hot. Switch off between readings.
- Check circuits before switching on to avoid short circuits. Keep water and drinks off the bench.
- All roles can be done seated; one learner can read meters while another times and records.
- Risk assess before use, following your employer's policy and SSERC guidance.

Common problems

- **Meter not reset:** charge keeps adding up. Reset or subtract the start reading.
- **Current drifting:** the rheostat warms up; take readings quickly and let it cool.
- **Uncertainty formula:** learners divide by the mean; stress (max − min) ÷ number of readings.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, graph, gradient and evaluation.

Assessment link

Evidence of planning and carrying out an experiment, recording, uncertainty, graph, conclusion and evaluation; good preparation for the assignment (raw data, mean, comparison with a source).

Answers: Topic 1

Topic 1: Electrical charge carriers (N5)

1 What is an electric current?

1 Free electrons.

2 3 coulombs every second.

3 The electrons are already in the wires and the lamp. The battery gives them energy and pushes them round; they are not used up. The same charge flows all the way round the circuit; the energy is transferred in the lamp.

2 Charge, current and time

1 $t = 5.0 \times 60 = 300$ s; $Q = I\,t = 0.60 \times 300 = 180$ C

2 $t = \frac{Q}{I} = 4.8 \times 10^5 \div 16 = 30\,000$ s = 8.3 hours

3 $I = 0.025$ A, $t = 24 \times 3600 = 86\,400$ s; $Q = I\,t = 0.025 \times 86\,400 = 2160$ C (2200 C)

3 Direct and alternating current

1 The right-hand trace: the voltage goes above and below zero, so the current changes direction.

2 A flat horizontal line at half the height above the centre line (1 square instead of 2).

3 d.c., e.g. a cell, battery or solar cell; a.c., e.g. the mains supply or a generator (alternator).

Practical 1: Current and charge

Variables: change the current (A); measure the charge passing in 60 s (C); keep the same: the time (60 s), the same coulomb meter, resetting to zero each time, the supply voltage setting.

Prediction, e.g. the charge will double when the current doubles, because $Q = I\,t$.

Equipment: d.c. supply, variable resistor, ammeter, coulomb meter, stopwatch, leads. Not needed: thermometer.

Hazards, e.g. short circuit (check the circuit before switching on); hot wires or resistor (low currents, switch off between readings).

Method key points: all in series; set the current with the variable resistor; reset the coulomb meter; switch on and time 60 s; read the charge; repeat 3 times; mean and uncertainty.

Sample means and uncertainties: 0.10 A: 6.0 ± 0.1 C; 0.20 A: 12.1 ± 0.1 C; 0.30 A: 18.1 ± 0.2 C; 0.40 A: 24.0 ± 0.2 C; 0.50 A: 30.0 ± 0.2 C.

Graph: a straight line through the origin. Conclusion: the charge is directly proportional to the current.

9(a) Gradient ≈ 60 C/A = 60 s, the time, as $Q = I\,t$. (b) $Q = 0.30 \times 60 = 18$ C; the mean (18.1 C) agrees within its uncertainty.

10(a) 0.40 A or 0.50 A (0.2 C to 0.3 C); more repeats, keep the current steady, start and stop the meter electronically. (b) The charge reading is bigger, so timing errors (reaction time) and the meter's resolution make a smaller percentage difference.

Check-up

1 The electric charge transferred per unit time (1).

2 $t = 2.5 \times 60 = 150$ s (1); $Q = I\,t = 13 \times 150$ (1); $Q = 1950$ C (2000 C) (1).

3 $t = \frac{Q}{I}$ (1); $t = 2.2 \times 10^5 \div 3.0$ (1); $t = 73\,000$ s (1) = 20 hours (1).

4 a.c. (1): the trace goes above and below zero, so the direction of the current keeps changing (1).

5 Mean $= \frac{18.4 + 17.8 + 18.0}{3} = 18.1$ C (1); uncertainty $= \frac{18.4 - 17.8}{3} = 0.2$ C (1).

TEACHER NOTES

Practical 2: Cells and potential difference

Time	About 30 minutes in pairs, leaving time for the graph and evaluation.
Kit per group	Four 1.5 V cells in holders (or a 4-cell holder with tapping points), a 6 V lamp in a holder, voltmeter (digital preferred), switch, leads.
Prep	Check cells are fresh and of the same type. A demonstration of field patterns (semolina in oil with a high-voltage supply) is a teacher-only option if your department has it and has risk assessed it.
Expected results	About 1.4–1.5 V per cell; slightly less than the nominal 1.5 V because of internal resistance. The lamp gets brighter with each cell.
Level	N5 plans, repeats, means and random uncertainties, line graph with line of best fit, explains using energy per coulomb, compares with the data sheet value.

Safety and inclusion

- Low voltage only. Short-circuited cells get hot and can leak; check polarity before switching on.
- Lamps get hot: do not touch. Switch off between readings.
- All roles can be done seated. A learner can read the meter while another records.
- Risk assess before use, following your employer's policy and SSERC guidance.

Common problems

- **A cell reversed:** the p.d. drops instead of rising. Check every cell is + to −.
- **Voltmeter in series:** the lamp will not light. The voltmeter goes across the lamp.
- **Field arrows:** learners draw arrows towards the positive plate. Stress: from + to −.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, graph, conclusion and evaluation.

Assessment link

Evidence of planning, recording, uncertainties, graph, conclusion and evaluation, and practice in comparing results with a published value as in the assignment.

Answers: Topic 2

Topic 2: Potential difference (N5)

1 Electric fields

1 A region where a charge experiences a force.

2 Curved lines from + to −, with a straight line between the centres; arrows from + towards −; lines do not cross.

3 Towards the positive plate (upwards in the diagram): electrons are negative, so the force is opposite to the field direction.

2 Charges moving in a field

1(a) Q. (b) P: it curves towards the positive plate, and opposite charges attract (the force on a negative charge is opposite to the field). (c) It curves more sharply (bends further towards the plate).

3 Potential difference and energy

1 12 J.

2 3.0 V; each coulomb receives 3.0 J.

3 9.0 − 6.5 = 2.5 V.

4 The 9 V battery gives each coulomb more energy (9 J rather than 1.5 J), and the current is larger, so more energy is transferred to the lamp each second as light and heat.

Practical 2: Cells and potential difference

Variables: change the number of cells; measure the p.d. across the lamp (V); keep the same: the lamp, the type of cell, the voltmeter, the circuit layout.

Equipment: 1.5 V cells in holders, 6 V lamp, voltmeter, leads. Not needed: stopwatch, balance.

Hazards, e.g. short circuits (check before switching on); hot lamp (do not touch).

Sample means and uncertainties: 1 cell: 1.45 ± 0.01 V; 2 cells: 2.90 ± 0.02 V; 3 cells: 4.33 ± 0.02 V; 4 cells: 5.74 ± 0.03 V.

Graph: a straight line through (or very close to) the origin. Conclusion: the p.d. is directly proportional to the number of cells (about 1.4 V per cell).

9(a) Each cell adds about 1.5 J to each coulomb, so with more cells each coulomb carries more energy to the lamp, and more charge flows each second, so more energy is transferred to light and heat. (b) Some energy is used inside the cell (internal resistance), so the p.d. across the lamp is a little less than the cell's voltage; or the cells are partly used.

10(a) More repeats; use fresh cells; use a digital voltmeter with good resolution; let the lamp settle before reading.

Check-up

1 Straight, parallel, evenly spaced lines from the + plate to the − plate (1), with arrows pointing towards the − plate (1).

2 Towards the positive plate (1).

3 It curves towards the negative plate (1) because positive charges are pushed along the field, towards the negative plate (1).

4 12 J of energy is given to each coulomb of charge (1).

5 8 V each (1); the p.d.s across components in series add up to the supply p.d., and identical lamps share it equally (1).

TEACHER NOTES

Practical 3: Does a resistor obey Ohm's law?

Time	One 50-minute lesson in pairs. Six p.d. settings with three repeats takes about 20 minutes.
Kit per group	Low-voltage d.c. supply (0–6 V), rheostat, 20 Ω resistor rated 5 W or more (at 6 V it dissipates 1.8 W, so a 2 W resistor runs hot), ammeter (0–1 A), voltmeter (0–10 V), leads. Optional: 6 V filament lamp for comparison.
Prep	Use a resistor with a high enough power rating that it stays cool. Check meter ranges. A filament lamp run as a second circuit shows the curved graph.
Expected results	Straight line through the origin, gradient about 20 Ω. The lamp gives a curve with resistance rising from a few ohms (cold) to tens of ohms.
Level	N5 plans, repeats, means and random uncertainties, line graph and gradient, compares with the labelled value and tolerance.

Safety and inclusion

- Low voltage only. Resistors and lamps get hot; switch off between readings and do not touch.
- Check circuits before switching on to avoid short circuits.
- All roles can be done seated; one learner can set the rheostat while another reads and records.
- Risk assess before use, following your employer's policy and SSERC guidance.

Common problems

- **Meters swapped:** an ammeter in parallel can blow its fuse. Check before switching on.
- **Axes swapped:** if I is on the y axis the gradient is 1/R. Insist on V against I.
- **Resistor warming:** readings drift upwards at higher currents; take readings quickly.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, graph, gradient and evaluation.

Assessment link

The Ohm's law experiment is a named course experiment. This practical gives evidence of planning, raw data, uncertainties, graph, gradient, comparison with a stated value and evaluation, as needed for the assignment.

Answers: Topic 3

Topic 3: Ohm's law (N5)

1 Resistance and Ohm's law

1 V = I R = 8.8 × 26 = 229 V (230 V)

2 $I = \frac{V}{R} = \frac{9.0}{2200} = 0.0041$ A = 4.1 mA

2 V–I graphs and temperature

1 Gradient = $\frac{6.0}{0.25}$ = 24 Ω.

2 As the current increases the filament gets hotter, and the resistance of a metal increases with temperature, so V rises faster than I.

3 A straight line through the origin with half the gradient (e.g. through 0.25 A, 3.0 V).

4 $R = \frac{V}{I} = \frac{12}{0.50}$ = 24 Ω; much bigger than when cold (3 Ω) because the hot filament has a higher resistance.

3 Resistors in series and parallel

1 R_T = 10 + 15 = 25 Ω

2 $1/R_T$ = 1/20 + 1/20 + 1/40 = 0.125, R_T = 8.0 Ω

3 Parallel pair: 1/R = 1/24 + 1/24, R = 12 Ω; total = 12 + 12 = 24 Ω

Practical 3: Does a resistor obey Ohm's law?

Variables: change the p.d. (V) using the rheostat; measure the current (A); keep the same: the resistor, its temperature (switch off between readings), the meters.

Equipment: supply, rheostat, resistor, ammeter, voltmeter, leads. Not needed: thermometer, stopwatch.

Sample means and uncertainties: 1.0 V: 0.050 ± 0.001 A; 2.0 V: 0.100 ± 0.001 A; 3.0 V: 0.150 ± 0.001 A; 4.0 V: 0.200 ± 0.001 A; 5.0 V: 0.249 ± 0.001 A; 6.0 V: 0.299 ± 0.001 A.

Graph: straight line through the origin. Conclusion: the current is directly proportional to the p.d., so the resistor obeys Ohm's law.

9(a) Gradient = $\frac{6.0}{0.300}$ = 20 Ω. (b) The filament heats up as the current increases, so its resistance increases.

10(a) 20 Ω ± 5% is 19 Ω to 21 Ω; 20 Ω is within the range.

Check-up

1 For a resistor at constant temperature, the current is directly proportional to the p.d. (1).

2 V = I R (1); 4.5 = 0.30 × R (1); R = 15 Ω (1).

3 $1/R_T = 1/R_1 + 1/R_2$ (1); $1/R_T = 1/6.0 + 1/3.0$ (1); R_T = 2.0 Ω (1).

4 R_T = 2.0 + 4.0 = 6.0 Ω (1); V = I R (1); 12 = I × 6.0 (1); I = 2.0 A (1).

5 The filament gets hotter as the current increases (1); the resistance of a metal increases as its temperature increases (1).

TEACHER NOTES

Practical 4: Thermistor and temperature

Time	One 50-minute lesson in pairs. Start with cold tap water and add hot water in steps; each reading needs about a minute to settle.
Kit per group	NTC thermistor with long leads (sealed or in a thin plastic sleeve), multimeter on a resistance range, thermometer (digital or spirit), 250 cm³ beaker on a tray, stirrer. The teacher has a kettle for hot water.
Prep	Waterproof the thermistor legs (heat-shrink or a sealed probe) so the water does not short the leads. Check the meter range suits about 0.4–3 kΩ.
Expected results	A falling curve, e.g. about 2.5 kΩ at 20 °C to about 0.4 kΩ at 70 °C for a 2.2 kΩ (at 25 °C) thermistor. Exact values depend on the part.
Level	N5 plans, repeats, means and random uncertainties, curve of best fit, interpolation, links to a switching circuit, compares with a data sheet.

Safety and inclusion

- Only the teacher handles water above 50 °C; learners do not move the beaker. Use a tray and wipe spills at once.
- Keep meters and mains equipment away from the water. Use low-voltage meters only.
- All roles can be done seated; one learner can read while another records.
- Risk assess before use, following your employer's policy and SSERC guidance.

Common problems

- **Readings drifting:** the thermistor has not reached the water temperature. Stir and wait.
- **Wrong meter range:** readings jump between Ω and kΩ; fix the range first.
- **Divider explanations:** learners say "the current goes to the transistor". Insist on the p.d. share chain.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, graph, conclusion and evaluation. A simulation of a potential divider circuit can replace the switching demonstration.

Assessment link

Evidence of planning, raw data, uncertainties, curved graphs, interpolation, linking results to an application, and comparison with published data, all useful for the assignment.

Answers: Topic 4

Topic 4: Practical circuits (N5)

1 Meters and circuit rules

1 12 − 7.5 = 4.5 V

2 0.20 + 0.35 + 0.45 = 1.00 A

3 It stays lit at the same brightness: it still has the full supply p.d. across it on its own branch.

2 Components and symbols

1 (a) fuse (b) diode (c) photovoltaic (solar) cell.

3 Potential dividers

1 V_2 = (2.2 ÷ (4.7 + 2.2)) × 9.0 = 2.9 V

2 $V_1/V_2 = R_1/R_2$: 2.0/10 = 600/R_2, R_2 = 3000 Ω (3.0 kΩ)

3 V_2 increases (the bigger resistor takes a bigger share of the p.d.).

4 Transistor switches

1 As it gets dark, the resistance of the LDR increases, so its share of the p.d. increases. The p.d. across the LDR (the base p.d.) rises; when it reaches about 0.7 V the npn transistor switches on and the LED lights.

2 To limit the current through the LED so it is not damaged.

Practical 4: Thermistor and temperature

Variables: change the temperature (°C); measure the resistance (kΩ); keep the same: the thermistor, the ohmmeter, the depth of the thermistor in the water, stirring and waiting before each reading.

Equipment: thermistor, ohmmeter, thermometer, beaker, kettle (used by the teacher). Not needed: ammeter.

Hazards, e.g. electrical leads near water (keep the meter dry and away from the beaker); glass thermometer breaking (use a digital or spirit thermometer, handle carefully).

Sample means and uncertainties: 20 °C: 2.49 ± 0.02 kΩ; 30 °C: 1.70 ± 0.02 kΩ; 40 °C: 1.15 ± 0.01 kΩ; 50 °C: 0.80 ± 0.01 kΩ; 60 °C: 0.58 ± 0.01 kΩ; 70 °C: 0.42 ± 0.01 kΩ.

Graph: a curve falling steeply at first and then more slowly. Conclusion: as the temperature increased, the resistance of the thermistor decreased.

9(a) About 0.95 kΩ (accept 0.9 to 1.0 kΩ). (b) As it warms, the thermistor's resistance falls, so its share of the supply p.d. falls and the gate p.d. rises until the MOSFET switches on.

10(a) The water is not stirred or the thermistor and thermometer are at different depths, or the thermistor has not reached the water temperature; stir, place them together and wait before reading.

Check-up

1 In parallel with (across) the resistor (1).

2 $V_2 = (R_2/(R_1 + R_2))\ V_s$ (1); V_2 = (3.0/(1.0 + 3.0)) × 12 (1); V_2 = 9.0 V (1).

3 It decreases (1): the thermistor now has a bigger share of the resistance, so it takes a bigger share of the p.d. (1).

4 $V_1/V_2 = R_1/R_2$ (1); 1.5/4.5 = 330/R_2 (1); R_2 = 990 Ω (1).

5 A transistor (MOSFET or npn) (1); it switches on when the p.d. across its gate (or base) reaches a set value (1).

TEACHER NOTES

Practical 5: How does power depend on voltage?

Time	One 50-minute lesson in pairs. Six voltages with three readings each takes about 25 minutes.
Kit per group	Variable low-voltage d.c. supply (0–12 V), ammeter (0–5 A), voltmeter (0–15 V), 12 V 24 W heater in an aluminium block, heatproof mat, leads.
Prep	A heater (or power resistor) is better than a filament lamp, because its resistance hardly changes; a lamp gives a curve on the P–V^2 graph. Check meter ranges.
Expected results	A straight line through the origin; gradient about 0.17 W/V^2 ($R \approx 6\ \Omega$). Readings drift upwards slightly if the heater is left on.
Level	N5 plans the test, repeats, finds means and random uncertainty, draws a P–V^2 graph and uses the gradient.

Safety and inclusion

- Low voltage only. Heaters stay in their blocks on heatproof mats; switch off between readings.
- All roles can be done seated. A learner can read one meter while a partner records.
- Risk assess this practical for your own learners, room and kit, following your employer's policies and SSERC guidance.

Common problems

- **Voltmeter in series:** the current is almost zero. It must go across the heater.
- **Plotting P against V:** gives a curve. The task asks for V^2 on the x axis.
- **Fuse answers:** learners choose by power (720 W rule) or by working out the current; both are fine.

No lab, no time, or a learner absent?

The sample results let learners complete the means, powers, graph, gradient and evaluation without the practical.

Assessment link

Practises assignment skills: raw data in a table with units, means and uncertainty, a graph with a line of best fit, comparing with a reference value and evaluating.

Answers: Topic 5

Topic 5: Electrical power (N5)

1 Power, energy and current

1 t = 300 s; $P = \frac{E}{t} = \frac{540\,000}{300} = 1800$ W

2 $I = \frac{P}{V} = \frac{160}{230} = 0.70$ A

3 The shower's power is much larger, so (at the same voltage) its current is much larger (about 41 A). A thin cable would overheat; a thick cable has a lower resistance and does not overheat.

2 Power and resistance

1 $P = V^2 / R = 12^2 \div 1.6 = 90$ W

2 $P = I^2 R = 450^2 \times 0.20 = 40\,500$ W (41 kW)

3 Power wasted is $I^2 R$, so it depends on the square of the current. Sending the same power at a high voltage needs a much smaller current, so far less energy is wasted as heat in the cables.

3 Choosing a fuse

1 Urn: 10.4 A, 13 A fuse. Projector: 1.2 A, 3 A fuse. Floor polisher: 3.7 A, 13 A fuse. Fan: 0.20 A, 3 A fuse.

2 The fuse must blow if there is a fault. A 13 A fuse would let a current big enough to overheat the fan's thin flex flow without blowing, so the flex could catch fire.

3 A kettle's power is above 720 W (about 2–3 kW), so its normal current (about 10–13 A) is more than 3 A and the fuse melts.

Practical 5: How does power depend on voltage?

Variables: change the voltage across the heater; measure the current (and voltage) and calculate the power; keep the same: the heater, the temperature of the heater (switch off between readings), the meters.

Prediction, e.g. the power will become four times bigger, because $P = V^2 / R$.

Equipment: variable supply, ammeter, voltmeter, 12 V heater, leads. Not needed: joulemeter, balance.

Hazards, e.g. short circuit making wires hot (check the circuit before switching on); supply set too high (do not go above 12 V); trailing leads (keep the bench tidy).

Method key points: ammeter in series with the heater, voltmeter in parallel across it; set the supply to 2, 4, 6, 8, 10, 12 V; read the current three times at each voltage, switching off between readings; $P = I V$; calculate V^2.

Headings: Voltage (V), I_1, I_2, I_3 (A), Mean current (A), Power (W), V^2 (V^2).

Sample results: 2 V: 0.34 A, 0.67 W, 4 V^2; 4 V: 0.67 A, 2.68 W, 16 V^2; 6 V: 1.00 A, 6.00 W, 36 V^2; 8 V: 1.34 A, 10.7 W, 64 V^2; 10 V: 1.67 A, 16.7 W, 100 V^2; 12 V: 2.00 A, 24.0 W, 144 V^2.

Graph: straight line through the origin.
Conclusion: power is directly proportional to the square of the voltage.

9a Gradient = $\frac{24}{144} = 0.167$ W/V^2, so $R = \frac{1}{0.167} = 6.0\ \Omega$ (accept 5.8 to 6.2 Ω).

9b $\frac{2.02 - 1.98}{3} = 0.01$ A.

10a So the heater does not warm up; its resistance (and the current) would change with temperature. 10b e.g. repeat the whole set of readings; take more voltages; use meters with more decimal places.

Check-up

1(a) $P = I V$ (1); $P = 8.7 \times 230$ (1); $P = 2000$ W (2001 W) (1)

1(b) $E = P t$ (1); $E = 2001 \times (45 \times 60)$ (1); $E = 5.4 \times 10^6$ J (1)

2 $P = V^2 / R$ (1); $P = 6.0^2 \div 15$ (1); $P = 2.4$ W (1)

3 A 3 A fuse (1), because 600 W is less than 720 W (or: $I = \frac{600}{230} = 2.6$ A, which is just below 3 A) (1).

TEACHER NOTES

Practical 6: The specific heat capacity of aluminium

Time	One 50-minute lesson for one run per group; three runs need the block to cool in between, so groups can share data or use several blocks.
Kit per group	1 kg aluminium block with heater and thermometer holes, 12 V 50 W immersion heater, low-voltage supply, joulemeter, thermometer or temperature probe, insulating jacket, heatproof mat, balance.
Prep	Check joulemeters reset to zero. A few drops of oil or water in the thermometer hole improve contact. Never switch a heater on outside the block.
Expected results	About 9500–10 000 J for a 10 °C rise in a 1 kg block, giving c around 950–1000 J/kg °C, higher than 902 J/kg °C. Keep heating after switch-off in mind: the temperature keeps rising for a short time, so take the highest reading.
Level	N5 plans the measurements, repeats, finds a mean and random uncertainty, compares with a data book value and evaluates.

Safety and inclusion

- Heaters and blocks get hot: heatproof mats, no touching, allow to cool before handling.
- Prefer digital probes to glass thermometers. Low voltage only.
- Risk assess this practical for your own learners, room and kit, following your employer's policies and SSERC guidance.

Common problems

- **Using the final temperature as ΔT:** subtract the start temperature.
- **Mass in grams:** convert to kg.
- **Joulemeter not reset:** subtract the starting reading.

No lab, no time, or a learner absent?

The sample results let learners calculate c, the mean and uncertainty, and complete the evaluation.

Assessment link

Practises assignment skills: raw data with units, calculated values, a mean with uncertainty, comparison with a referenced data value and evaluation.

Answers: Topic 6

Topic 6: Specific heat capacity (N5)

1 Heat and temperature

1 Temperature is the mean kinetic energy of the particles; the bath has far more particles (a much larger mass), so its total heat energy can be greater even though each particle has less kinetic energy on average.

2 Sand has a smaller specific heat capacity than water (830 against 4180 J/kg °C), so the same energy gives sand a much bigger rise in temperature.

2 Calculating the energy

1 $E_h = c\ m\ \Delta T = 386 \times 1.2 \times 160 = 74\,112$ J, so 7.4×10^4 J

2 $\Delta T = \frac{E_h}{c\ m} = \frac{36\,000}{902 \times 0.80} = 49.9$ °C, so 50 °C

3 $c = \frac{E_h}{m\ \Delta T} = 1.0 \times 10^5 \div (4.2 \times 15) = 1587$, so 1600 J/kg °C

3 Conservation of energy

1 $E = P\ t = 50 \times 300 = 15\,000$ J; $\Delta T = \frac{E}{c\ m} = \frac{15\,000}{480 \times 1.0} = 31$ °C (31.25 °C)

2 Some heat is lost from the block to the surroundings (air, bench), so less than 15 000 J goes into the block.

3 Insulation reduces the heat lost to the surroundings, so less electrical energy is needed to keep the water hot.

Practical 6: The specific heat capacity of aluminium

Measure: mass of the block (kg), energy supplied (J) from the joulemeter, start and final temperature (°C). Keep the same: the block, the insulation, the heater, the temperature rise (about 10 °C).

Prediction, e.g. higher, because some of the energy supplied is lost as heat to the surroundings.

Equipment: 12 V supply, joulemeter, 12 V heater, thermometer, balance. Not needed: stopwatch, ammeter.

Hazards, e.g. hot block and heater (heatproof mat, allow to cool); thermometer breaking (glass; use a digital probe or handle carefully); heater used outside the block (only switch on when it is in the hole).

Method key points: weigh the block; insulate it; put the heater and thermometer in their holes (a drop of oil helps contact); reset the joulemeter; note the start temperature; heat until about 10 °C rise, switch off and note the highest temperature; $c = \frac{E}{m\ \Delta T}$; repeat after cooling.

Headings: Run, Energy (J), Start temperature (°C), End temperature (°C), ΔT (°C), c (J/kg °C).

Sample results: run 1: ΔT = 10.0 °C, c = 948 J/kg °C; run 2: ΔT = 10.1 °C, c = 962 J/kg °C; run 3: ΔT = 9.9 °C, c = 970 J/kg °C. Mean = 960 J/kg °C; random uncertainty = $\frac{970 - 948}{3} = 7$ J/kg °C. Result c = 960 ± 7 J/kg °C.

8a Higher than 902 J/kg °C. 8b Heat is lost to the surroundings and used to warm the heater and thermometer, so more energy is supplied than goes into the block; dividing a too-large E by m ΔT gives a too-large c.

9a e.g. better insulation (less heat lost); oil or water in the holes (better thermal contact so the thermometer reads the true temperature); larger temperature rise (smaller percentage uncertainty in ΔT); a lid of insulation on top. 9b The joulemeter measures the energy actually supplied; the power rating is only approximate and timing adds reaction-time error.

Check-up

1 The mean kinetic energy of its particles. (1)

2(a) $E_h = c\ m\ \Delta T$ (1); $E_h = 4180 \times 140 \times 43$ (1); $E_h = 2.5 \times 10^7$ J (25 163 600 J) (1)

2(b) $t = \frac{E}{P}$ (1); $t = 2.516 \times 10^7 \div 3000$ (1); $t = 8400$ s (8388 s) (1)

3 $\Delta T = \frac{E_h}{c\ m}$ (1); $\Delta T = \frac{3200}{128 \times 0.50}$ (1); ΔT = 50 °C (1)

TEACHER NOTES

Practical 7: The latent heat of fusion of ice

Time	One 50-minute lesson. Each energy reading takes a few minutes; groups can share the five energies and pool results.
Kit per group	Two large funnels in stands, two beakers, crushed ice (enough to refill), 12 V 50 W heater, low-voltage supply, joulemeter, balance (0.1 g).
Prep	Crush ice in advance and let it stand so it is at 0 °C and starting to melt. Pack the ice firmly round the heater. Keep electrics on a separate, dry part of the bench.
Expected results	About 18 g of extra ice melted for every 6 kJ, giving l close to 3.3×10^5 J/kg. Values are often a little high (some energy warms the funnel) or low (water clinging to ice).
Alternative	A cooling curve of a low-melting wax (such as stearic acid in a water bath, teacher-heated) shows latent heat being given out as a flat section. Follow your local guidance for the substance used.
Level	N5 plans the test with a control, repeats, finds means and uncertainty, uses a graph gradient and compares with a data value.

Safety and inclusion

- Water and electricity: low voltage only, supply and joulemeter away from the funnels, mop spills at once.
- Only switch the heater on when it is packed in ice. Cold hands: allow gloves for handling ice.
- Risk assess this practical for your own learners, room and kit, following your employer's policies and SSERC guidance.

Common problems

- **Forgetting the control:** the room melts ice too; subtract the control mass.
- **Grams and kilograms:** l uses kg.

No lab, no time, or a learner absent?

The sample results let learners find means, draw the graph, use the gradient and evaluate.

Assessment link

Practises assignment skills: a controlled experiment, raw data with units, means with uncertainty, a graph with line of best fit, comparing with a data value.

Answers: Topic 7

Topic 7: Specific latent heat (N5)

1 Changing state

1 First flat part: the ice is melting (at 0 °C). Second flat part: the water is boiling (at 100 °C). The temperature stays the same while the state changes.

2 The energy supplied is used to break the bonds between the particles, not to increase their kinetic energy, so the mean kinetic energy (temperature) does not change.

3 Steam gives out its latent heat of vaporisation as it condenses on the skin, as well as the heat from cooling, so it transfers much more energy to the skin.

2 Calculating latent heat

1 $E_h = m\,l = 2.5 \times 3.34 \times 10^5 = 8.4 \times 10^5$ J (835 000 J)

2 $E_h = m\,l = 0.12 \times 22.6 \times 10^5 = 2.7 \times 10^5$ J (271 200 J)

3 $l = \frac{E_h}{m} = \frac{46\,000}{0.25} = 1.8 \times 10^5$ J/kg (184 000 J/kg)

3 Two-stage problems and cooling curves

1 Freezing point 70 °C; it took 6 minutes to freeze (from 3 to 9 minutes).

2 $E_h = m\,l = 0.20 \times 22.6 \times 10^5 = 452\,000$ J (4.5×10^5 J). Heating from 20 °C to 100 °C needs only $c\,m\,\Delta T = 4180 \times 0.20 \times 80 = 66\,880$ J; the latent heat of vaporisation is very large because all the bonds must be broken to separate the particles.

3 Sweat evaporates from the skin. Evaporation needs latent heat, which is taken from the skin, so the skin cools.

Practical 7: The latent heat of fusion of ice

Variables: change the energy supplied (joulemeter); measure the extra mass of ice melted (heated minus control); keep the same: the amount and size of crushed ice, the funnels, the time for each run, the room.

Control: the control funnel shows how much ice the room melts, so this can be subtracted and only the heater's effect is measured.

Equipment: 12 V supply, joulemeter, 12 V heater, beakers (and funnels), balance. Not needed: thermometer (the ice stays at 0 °C).

Hazards, e.g. heater hot if switched on out of the ice (only switch on when surrounded by ice); slippery wet floor (mop up); glass beakers breaking (handle carefully).

Method key points: two identical funnels packed with crushed ice, heater in one only; wait until water is dripping from both; empty the beakers, reset the joulemeter and start; collect water for the same time from both; weigh both; extra mass = heated − control; repeat; $l = \frac{E}{m.}$

Headings: Energy (J), Extra mass 1, 2, 3 (g), Mean extra mass (g).

Sample results (means): 6000 J: 18.5 g; 12000 J: 36.4 g; 18000 J: 54.9 g; 24000 J: 71.6 g; 30000 J: 90.3 g.

8a Mean 54.9 g, random uncertainty $\frac{55.6 - 54.1}{3} = 0.5$ g, so 54.9 ± 0.5 g.

8b Gradient ≈ 2.99 g per kJ; $l = \frac{E}{m} = \frac{1}{\text{gradient}}$ ≈ 3.3×10^5 J/kg (334262 J/kg; accept 3.2 to 3.4 × 10^5 J/kg).

9a Close to 3.34×10^5 J/kg. A difference could come from some heater energy warming the funnel or air, or water clinging to the ice and funnel.

9b So that all the energy from the heater melts ice; if the ice were below 0 °C some energy would first warm it up.

Check-up

1 The energy needed to change 1 kg of water (liquid) into steam (gas) at its boiling point, with no change in temperature. (1)

2(a) $E_h = m\,l$ (1); $E_h = 85 \times 3.34 \times 10^5$ (1); $E_h = 2.8 \times 10^7$ J (28 390 000 J) (1)

2(b) $E_h = c\,m\,\Delta T$ (1); $E_h = 4180 \times 85 \times 6$ (1); $E_h = 2.1 \times 10^6$ J (2 131 800 J) (1)

3 The energy is used to change the water into steam (it breaks the bonds between particles) rather than raise the temperature. (1)

TEACHER NOTES

Practical 8: The pressure law

Time	One 50-minute lesson. Heating from room temperature to 80 °C and reading every 10 °C takes about 20 minutes; readings on cooling give the repeats.
Kit per group	Round-bottomed flask (or the standard sealed sphere apparatus) with short, thick-walled tubing to a Bourdon gauge or pressure sensor, large beaker water bath, thermometer, stirrer, clamp stand, eye protection. The teacher heats the bath.
Prep	Check the flask and tubing for cracks and leaks. Clamp the flask so it does not float. Heat the bath up to 80 °C at most; only the teacher handles the bath water above 50 °C.
Expected results	A straight line, about 0.35 kPa per °C from about 101 kPa at 20 °C. Extending it back gives absolute zero close to −273 °C (often within ±20 °C).
Level	N5 plans the test, repeats, finds means and uncertainty, extrapolates a graph and evaluates.

Safety and inclusion

- Hot water: the teacher heats and handles water above 50 °C; learners stay seated and read the gauge and thermometer.
- Glass under pressure: eye protection for everyone; clamp the flask; inspect glassware first.
- Risk assess this practical for your own learners, room and kit, following your employer's policies and SSERC guidance.

Common problems

- **Using °C in p / T:** gas law calculations need kelvin.
- **Graph axes:** learners need a temperature axis reaching −300 °C to extrapolate.
- **Long tubing:** air outside the bath is not heated, so the pressure rises too little.

No lab, no time, or a learner absent?

The sample results let learners find means and uncertainty, draw and extrapolate the graph, and evaluate.

Assessment link

Practises assignment skills: raw data with units, means and uncertainty, a graph with a line of best fit and extrapolation, comparing with the accepted value of absolute zero.

Answers: Topic 8

Topic 8: Gas laws and the kinetic model (N5)

1 Pressure and the kinetic model

1 The same force (the walker's weight) acts over a much larger area, so the pressure on the snow is much smaller.

2 $F = p\,A = 2.4 \times 10^5 \times 0.015 = 3600$ N

3 There are more particles in the same volume, so there are more collisions with the walls each second; the force on each square metre is greater.

2 Absolute zero and the pressure law

1 (a) 310 K (b) −196 °C

2 $T_1 = 280$ K, $T_2 = 308$ K; $p_1 / T_1 = p_2 / T_2$; $\frac{230}{280} = p_2 \div 308$; $p_2 = 253$ kPa

3 The particles move faster, so they hit the walls more often and harder; the force on the walls increases, so the pressure increases.

3 The gas laws

1 $p_1V_1 = p_2V_2$; $100 \times 60 = 150 \times V_2$; $V_2 = 40$ cm³

2 As it rises the outside pressure falls; the helium pushes the balloon out until the inside pressure matches the outside, so the volume increases (the fall in pressure has a bigger effect than the fall in temperature).

Practical 8: The pressure law

Variables: change the temperature of the water bath (and so the air); measure the pressure; keep the same: the volume of air (same flask), the mass of air (no leaks), the gauge.

Prediction: the pressure will increase, because the particles move faster and hit the walls harder and more often.

Equipment: water bath (with teacher heater), thermometer, clamp stand, eye protection, flask and pressure gauge. Not needed: joulemeter.

Hazards, e.g. glass flask under pressure could crack (eye protection, clamp the flask, go no higher than 80 °C; teacher only above 50 °C); hot clamp and flask (do not touch); water near the heater's electrics (teacher sets up).

Method key points: the flask almost fully under the water; short tubing so nearly all the air is heated; stir and wait for the temperature to steady before each reading; read the gauge at each temperature on heating, cooling and reheating; find the mean.

Sample results (means): 20 °C: 101.0 kPa; 30 °C: 104.4 kPa; 40 °C: 107.8 kPa; 50 °C: 111.3 kPa; 60 °C: 114.8 kPa; 70 °C: 118.2 kPa; 80 °C: 121.7 kPa.

8a 111.3 kPa ± 0.2 kPa. 8b The line meets zero pressure at about −272 °C (accept −260 °C to −290 °C), close to −273 °C. 8c p ÷ T(K) is about 0.345 kPa/K each time: pressure is directly proportional to kelvin temperature.

9a e.g. air in the tubing is not heated (use short, narrow tubing); the thermometer reads the water, not the air (wait for steady readings and stir); the gauge scale is coarse (use a digital pressure sensor).

Check-up

1 The lowest possible temperature, 0 K or −273 °C, where the particles have the least kinetic energy (and a gas would exert no pressure). (1)

2(a) $p_1 / T_1 = p_2 / T_2$ (1); $1.8 \times 10^6 \div 288 = p_2 \div 588$ (1); $p_2 = 3.7 \times 10^6$ Pa (3 675 000 Pa) (1)

2(b) The particles move faster (1), so they hit the walls of the cylinder more often and with more force, increasing the pressure (1).

3 $p_1V_1 = p_2V_2$ (1); $250 \times 1.5 = 100 \times V_2$ (1); $V_2 = 3.8$ cm³ (3.75 cm³) (1)

About the author

C. Blewis has taught for 17 years, including 10 years in Additional Support Needs (ASN) provision, teaching sciences, maths, PE and more.

In many schools, especially smaller and specialist settings, teachers are often asked to teach outside their own subject. These books are written for them, and for the young people they teach: clear, practical and ready to use from the first lesson.