REAL-LIFE PHYSICS

Electricity and Energy

Teacher guide

For the National 4 Physics workbook



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Blewis LEARNING

Using the workbooks

The National 4 Physics workbook for **Electricity and Energy** has ten topics. Every topic has learning pages, a practical the learner plans and evaluates, a brain break and a 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.

Contents

Topic 1	Generating electricity	**4**
Topic 2	Energy for the future	**6**
Topic 3	Power and energy	**9**
Topic 4	Efficiency	**11**
Topic 5	Magnets and electromagnets	**14**
Topic 6	Transformers and the National Grid	**16**
Topic 7	Series and parallel circuits	**18**
Topic 8	Resistance and V = IR	**20**
Topic 9	Electronic systems	**22**
Topic 10	Gases and the kinetic model	**24**

TEACHER NOTES

Practical 1: What affects the output of a solar cell?

Time	One 50-minute lesson in pairs or threes, plus time to finish the analysis.
Kit per group	Small solar cell (photovoltaic cell) with leads, ammeter or multimeter on the milliamp range, desk lamp (a filament or halogen lamp gives a strong output; a bright LED lamp is cooler), metre stick, blackout or a shoebox to shade the bench.
Prep	Darken the room if possible. Test one cell at 10 cm to choose the ammeter range. Measure the current, not the voltage: the voltage of a solar cell changes very little with light level, so it makes a poor dependent variable.
Expected results	Current falls quickly as the lamp moves away, then levels off (roughly halving when the distance goes from 10 to 20 cm). Exact values depend on the cell and lamp; tens of milliamps at 10 cm is typical for a small cell.
Alternative	Keep the distance fixed and change the **angle** of the cell (0° to 80° with a protractor). The current is greatest when the cell faces the lamp.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages and draws a line graph with their own scales.

Safety and inclusion

- Filament and halogen lamps get very hot. Move lamps by the base and let them cool. Check plugs and cables before use.
- Learners should not stare into the lamp. Keep drinks and water away from mains equipment.
- All roles can be done seated. Learners who find reading small scales hard can use a digital meter or be the recorder.
- Follow your school and local authority guidance on practical work.

Common problems

- **Background light:** windows and room lights raise every reading. Shade the cell or subtract a "lamp off" reading.
- **Lamp heating the cell:** very close distances can warm the cell. Do not go closer than 10 cm and take readings quickly.
- **Changing angle by accident:** fix the cell to a block so it always faces the lamp.

No lab, no time, or a learner absent?

The sample results let learners complete the averages, graph, conclusion and evaluation without doing the practical.

Assessment link

Gives evidence of planning and carrying out an experiment safely, recording and presenting results, drawing a conclusion and evaluating, and links to the generation of electricity key area of the unit.

Answers: Topic 1

Topic 1: Generating electricity (N4)

1 Energy sources

1 Renewable: wind, hydro, wave, tidal, solar, biomass. Non-renewable: gas, coal, oil, nuclear.

2 It took millions of years to form and we are using it much faster than it forms, so it will run out.

3 Any two: they will run out; burning them releases carbon dioxide which adds to climate change; other pollution such as smoke; prices can rise as supplies fall; need to import fuel.

2 How a power station works

1 fuel → boiler → steam → turbine → generator.

2 nuclear → heat → kinetic → electrical.

3 It changes kinetic energy (the spinning turbine) into electrical energy.

3 Advantages and disadvantages

1 Advantage e.g. renewable, no fuel cost, no carbon dioxide while running, Scotland is windy. Disadvantage e.g. no output when the wind is calm (or too strong), visual impact, noise, can harm birds.

2 Partly agree or disagree with a reason: solar still works on cloudy days and is useful in summer when days are long; but output is low in winter and zero at night, so Scotland cannot rely on solar alone.

3 Wind is not reliable: on calm days there is little output. Gas and hydro can be switched on quickly to keep the supply matching demand.

Practical 1: Output of a solar cell

Variables: change the distance from the lamp to the cell (cm); measure the current from the cell (mA); keep the same: lamp and bulb, angle of the cell, the same cell and ammeter, room lighting (lights off), how long the lamp has been on.

Prediction, e.g. the further the lamp, the smaller the current, because less light reaches the cell.

Equipment: solar cell, desk lamp, ammeter, leads, metre stick. Not needed: stopwatch, balance.

Hazards, e.g. trailing lamp cable (keep tidy on the bench); bright light in eyes (do not stare into the lamp); lamp falling off the bench (keep it back from the edge); mains lamp near water (no drinks or water on the bench).

Method key points: connect cell straight to the ammeter (in series); set distance with the metre stick from lamp bulb to cell face; room lights off, cell facing the lamp; read the current at each distance (e.g. every 10 cm from 10 cm to 50 cm); repeat each 3 times and average.

Headings: Distance (cm), Current 1, 2, 3 (mA), Average current (mA).

Sample averages: 10 cm 49 mA; 20 cm 26 mA; 30 cm 15 mA; 40 cm 10 mA; 50 cm 6.7 mA.

Graph: distance (cm) on the x axis, average current (mA) on the y axis, even scales, smooth curve falling steeply then levelling off.

Conclusion: as the distance increased, the current from the solar cell decreased (quickly at first, then more slowly).

Explain: the light spreads out as it travels, so less light energy reaches each part of the cell further away, and the cell transfers less electrical energy.

Evaluate: (a) extra light makes the current higher than it should be, especially at large distances where the lamp's light is weak. (b) e.g. black out the room or use a box/tube; keep the lamp on for the same time so it is warmed up; more repeats; smaller steps in distance; measure from the bulb itself.

Check-up

1 e.g. renewable: wind, solar, hydro, wave, tidal, biomass; non-renewable: coal, oil, gas, nuclear.

2 gravitational potential → kinetic → electrical.

3 Steam (made by burning the gas to boil water).

4 Advantage e.g. reliable, huge output from little fuel, no carbon dioxide while running. Disadvantage e.g. radioactive waste lasts thousands of years, very expensive to build and close down, non-renewable, risk of accidents.

5 The current increases, because more light reaches the solar cell so more light energy is changed into electrical energy.

TEACHER NOTES

Practical 2: What affects the output of a wind turbine?

Time	One 50-minute lesson in pairs or threes, plus time to finish the analysis.
Kit per group	Model wind turbine with small generator (kit versions with adjustable blades are ideal), voltmeter or multimeter, leads, desk fan with speed settings, metre stick, clamp or heavy base for the turbine.
Prep	Check that each turbine turns freely and gives a reading at about 20 cm on the highest fan setting. Set multimeters to the 20 V DC range.
Expected results	Voltage falls as the fan moves away, quickly at first, then more slowly. A few volts close up falling to around half a volt at 1 m is typical, but kits vary a lot. Readings flicker, so ask learners to wait for a steady value.
Alternatives	Change the **number of blades** (2, 3, 4, 6) or the **blade angle** at a fixed distance. Results often show a best number or angle rather than a steady trend, which makes a good discussion.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages and draws a line graph with their own scales.

Safety and inclusion

- Use fans with guards. Keep fingers, hair and loose clothing away from spinning blades. Switch off and wait for blades to stop before adjusting.
- Clamp or weight the turbine so it cannot topple. Keep mains cables tidy and away from the edge of the bench.
- All roles can be done seated. Learners sensitive to noise can work at the low fan setting or be the recorder.
- Follow your school and local authority guidance on practical work.

Common problems

- **Flickering readings:** agree a rule, such as watching for 10 seconds and recording the middle value.
- **Turbine not facing the fan:** mark the floor positions and keep both on the same line.
- **Draughts:** open windows or other groups' fans affect results. Space groups apart.

No lab, no time, or a learner absent?

The sample results let learners complete the averages, graph, conclusion and evaluation without doing the practical.

Assessment link

Gives evidence of planning and carrying out an experiment safely, recording and presenting results, drawing a conclusion and evaluating, and links to energy for the future and generation of electricity in the unit.

Answers: Topic 2

Topic 2: Energy for the future (N4)

1 A sustainable energy supply

1 It meets our energy needs now without running out or harming the environment for people in the future.

2 Advantage e.g. free electricity from sunlight, lower bills, sell spare to the grid, no carbon dioxide. Disadvantage e.g. expensive to buy, little output in winter and none at night, needs a suitable (south-facing) roof.

3 When there is spare electricity, water is pumped up to a high reservoir. When the wind stops and more electricity is needed, the water flows down through turbines and generates electricity within minutes.

2 Island challenge

1 2 × 90 + 60 + 100 + 30 = 370 kW. Yes, this is more than the average demand of 300 kW.

2 Wind turbines (calm) and solar panels (dark) give nothing. Hydro 60 kW + tidal 100 kW = 160 kW (less when the tide turns). Demand up to 500 kW, so up to 340 kW is still needed.

3 Any sensible plan with reasons, e.g. 3 wind turbines, hydro, tidal and solar for most of the energy; a battery to store spare energy from windy days and cover evening peaks; keep the diesel generator only as an emergency backup for long calm spells, because it is reliable but releases carbon dioxide and fuel must be shipped in. Saving energy (insulation, LED lamps) also cuts the peak.

3 Losses in the grid

1 A high voltage means a small current, so less energy is wasted as heat in the cables.

2 It lowers the voltage to a safe level for homes (230 V).

3 Either with two reasons, e.g. underground: protects the view of the glen, safe from storms, no risk to birds. Overhead: much cheaper, easier to repair, less digging that disturbs the land.

Practical 2: Output of a wind turbine

Variables: change the distance from the fan to the turbine (cm); measure the voltage from the turbine (V); keep the same: fan and its speed setting, the same turbine and blades, blade angle, turbine facing the fan, height of fan and turbine.

Prediction, e.g. the further away the fan, the lower the voltage, because the air is moving more slowly when it reaches the blades.

Equipment: desk fan, model turbine, voltmeter, leads, metre stick. Not needed: balance, desk lamp.

Hazards, e.g. fan or turbine falling off the bench (keep back from the edge, clamp the turbine); trailing cables (tidy away); long hair or loose clothing near blades (tie back).

Method key points: connect the turbine to the voltmeter; measure from the fan to the turbine with the metre stick; switch on the fan and wait for the turbine to reach a steady speed; read the voltage (or a middle value); test e.g. 20, 40, 60, 80, 100 cm; repeat 3 times and average.

Headings: Distance (cm), Voltage 1, 2, 3 (V), Average voltage (V).

Sample averages: 20 cm 2.42 V; 40 cm 1.62 V; 60 cm 1.10 V; 80 cm 0.75 V; 100 cm 0.50 V.

Graph: distance (cm) on the x axis, average voltage (V) on the y axis, even scales, smooth curve falling as distance increases.

Conclusion: as the distance from the fan increased, the voltage from the turbine decreased.

Explain: the air slows down and spreads out as it moves away from the fan, so it has less kinetic energy to turn the blades. The turbine spins more slowly and generates less electrical energy.

Evaluate: (a) e.g. wait for a steady reading and take the middle value, or take several readings over 10 s and average; use a data logger. (b) Turbines should go where the wind is strongest and most steady, such as the top of the windy hill or an open coast, because faster wind gives a bigger output.

Check-up

1 Any two: use more renewable sources; store energy (batteries, pumped storage); use a mix of sources; reduce energy waste and demand; microgeneration.

2 Small-scale generation where the electricity is used, e.g. solar panels on a house roof, a small wind turbine on a farm, a micro-hydro scheme on a burn.

3 Wind and solar depend on the weather and time of day, so output may be low when demand is high (calm, dark winter evenings).

4 A high voltage means a small current, which reduces the energy lost as heat in the cables.

5 Advantage e.g. hidden, not damaged by storms or ice, safer for birds. Disadvantage e.g. much more expensive, harder to find and repair faults, digging disturbs land.

TEACHER NOTES

Practical 3: How powerful is each device?

Time	One 50-minute lesson in pairs or threes. Four devices at 3 × 120 s each takes about 30 minutes of running time; groups can share devices on a carousel.
Kit per group	Joulemeter, low-voltage power supply (12 V), leads, stopwatch, 12 V filament lamp and an LED lamp in holders, 12 V heater in an aluminium block on a heatproof mat, small 12 V motor with a fan blade.
Prep	Check each joulemeter resets and reads in joules. Never run a heater in air: it must sit in its metal block (or in water). Check device ratings match the supply.
Expected results	Close to the rated powers: e.g. a 24 W lamp gives about 2900 J in 120 s; a 50 W heater about 6000 J. Ranking: heater, filament lamp, motor, LED. Exact values depend on the supply voltage.
Mains option	As a teacher demonstration, a plug-in energy meter can show the power of a kettle, toaster or fan heater directly. Most read energy in kWh to 0.01, so leave appliances on long enough for a clear reading. Learners do not handle mains plugs or hot water.
Level	N4 plans the test, repeats readings, averages, calculates power and draws a bar chart with their own scale.

Safety and inclusion

- Lamps and heaters get hot: heatproof mats, no touching for several minutes after use. Switch off before changing devices.
- Keep fingers away from motor fan blades. Keep water and drinks off the bench.
- All roles can be done seated. A learner who finds reading the meter difficult can work the stopwatch or record.
- Follow your school and local authority guidance on practical work.

Common problems

- **Joulemeter not reset:** readings keep adding up. Reset, or subtract the start reading.
- **Wrong terminals:** the supply goes to "in" and the device to "out".
- **Time in minutes:** remind learners to use seconds in $P = \frac{E}{t}$.

No lab, no time, or a learner absent?

The sample results let learners complete the averages, powers, bar chart, conclusion and evaluation without doing the practical.

Assessment link

Gives evidence of planning and carrying out an experiment safely, recording and presenting results, drawing a conclusion and evaluating, and of using P = E / t in a practical context.

Answers: Topic 3

Topic 3: Power and energy (N4)

1 What is power?

1 800 W = 0.8 kW; 9.5 kW = 9500 W; 1500 W = 1.5 kW; 0.6 kW = 600 W.

2 The electric shower (9000 W). It heats water as it flows, which needs a lot of energy every second.

3 Power is energy per **second**: 60 W means 60 J every second (3600 J every minute).

2 The power relationship

1 $P = \frac{E}{t} = \frac{36\,000}{30} = 1200$ W

2 $E = P\,t = 100 \times 600 = 60\,000$ J

3 $t = \frac{E}{P} = \frac{360\,000}{2000} = 180$ s

3 Units and energy at home

1 P = 3000 W, t = 600 s; $E = P\,t = 3000 \times 600 = 1\,800\,000$ J (1800 kJ)

2 E = 72 000 J, t = 1.2 × 60 = 72 s; $P = \frac{E}{t} = \frac{72\,000}{72} = 1000$ W (1 kW)

3 Any two, e.g. switch off appliances and lights when not in use (not on standby); only boil the water needed; use LED lamps; use a lower-power or more efficient appliance; use heating appliances for less time; insulate the building; turn the heating down a little.

Practical 3: How powerful is each device?

Variables: change the device; measure the energy used (J) in the set time, then work out the power (W); keep the same: the time switched on (120 s), supply voltage (12 V), the same joulemeter, starting each test from zero.

Prediction, e.g. the heater will be most powerful because heating needs the most energy each second.

Equipment: joulemeter, 12 V power supply, leads, stopwatch, 12 V lamps, 12 V heater. Not needed: balance.

Hazards, e.g. hot lamp (do not touch, let it cool); short circuit or overheating wires (check the circuit before switching on, switch off between tests); spinning motor or fan blades (keep fingers clear).

Method key points: power supply to the joulemeter "in" terminals, device to the "out" terminals; reset (or note) the joulemeter reading; switch on and start the stopwatch together; switch off after 120 s and read the energy; repeat 3 times per device; average; $P = \frac{E}{t.}$

Headings: Device, Energy 1, 2, 3 (J), Average energy (J), Power (W).

Sample results: filament lamp 2885 J, 24 W; LED lamp 362 J, 3.0 W; heater 5760 J, 48 W; motor 801 J, 6.7 W.

Bar chart: devices on the x axis, power (W) on the y axis with an even scale (e.g. 0 to 50 W), bars of equal width with gaps.

Conclusion: the heater had the greatest power (48 W) and the LED lamp the smallest (3 W).

Explain: (a) the LED lamp: it gives the same light for much less power, so it wastes less energy as heat and costs less to run. (b) Heating something needs a lot of energy each second, so heat-producing devices transfer energy quickly.

Evaluate: (a) a longer time gives a bigger energy reading, so small timing errors (reaction time) and the meter's resolution matter less. (b) e.g. more repeats; reset the joulemeter to zero each time; let the heater cool between tests; use a data logger to switch off exactly.

Check-up

1 800 joules of energy are transferred every second.

2 t = 5 × 60 = 300 s; $P = \frac{E}{t} = \frac{4500}{300} = 15$ W

3 P = 9000 W, t = 6 × 60 = 360 s; $E = P\,t = 9000 \times 360 = 3\,240\,000$ J (3240 kJ)

4 E = 96 000 J, P = 1200 W; $t = \frac{E}{P} = \frac{96\,000}{1200} = 80$ s

5 Kettle and fan heater.

TEACHER NOTES

Practical 4: How efficient is an electric motor?

Time	One 50-minute lesson in groups of three: one switches the motor, one watches the mark, one records.
Kit per group	Small low-voltage motor with a pulley or axle, clamp stand and boss (or G-clamp), thread, 100 g slotted mass hanger and masses, metre stick, joulemeter (reading to 0.1 J if possible), low-voltage supply, leads, soft landing tray.
Prep	Fix motors at the bench edge so the mass can be wound up from the floor. Mark a height (0.80 m works well). Check the motor can lift 500 g; if not, use 50 g steps. Learners are given E_p = m g h; it is not an N4 relationship they need to recall.
Expected results	Small motors are inefficient: typically about 10 % to 25 %. Efficiency usually rises with load at first and then levels off or falls if the motor struggles. Very light loads give low efficiencies because most energy goes into spinning the motor itself.
Alternative	Compare heating 250 ml of water by 50 °C in a kettle and a microwave, using a plug-in energy meter for input and E = c m ΔT given for output. Teacher handles all hot water and mains appliances.
Level	N4 plans the test, repeats readings, averages, calculates efficiency and draws a line graph with their own scales.

Safety and inclusion

- Masses can fall: soft tray underneath, feet clear, lift no higher than needed. Clamp the stand firmly to the bench.
- Motors can get warm after repeated runs. Keep fingers away from the turning axle.
- All roles can be done seated. The recorder role suits learners who find fine control of the switch difficult.
- Follow your school and local authority guidance on practical work.

Common problems

- **Stopping late or early:** input energy changes. Agree a clear mark and use one person to call "stop".
- **Thread slipping:** tape the end of the thread to the axle.
- **Joulemeter resolution:** if it only reads whole joules, use a greater height or heavier masses.

No lab, no time, or a learner absent?

The sample results let learners complete the averages, efficiencies, graph, conclusion and evaluation without doing the practical.

Assessment link

Gives evidence of planning and carrying out an experiment safely, recording and presenting results, drawing a conclusion and evaluating, and of calculating percentage efficiency.

Answers: Topic 4

Topic 4: Efficiency (N4)

1 Useful and wasted energy

1 Kettle: wasted heat in the kettle body and surroundings (and sound). Motor: useful kinetic energy; wasted heat (and sound). Loudspeaker: useful sound; wasted heat.

2 500 − 350 = 150 J wasted, mostly as heat (some sound).

3 The LED lamp. Its wasted (heat) arrow is narrower and its useful (light) arrow is wider: 60 J wasted compared with 90 J.

2 Calculating efficiency

1 eff = $\frac{\text{useful}}{\text{input}} \times 100 = \frac{180\ 000}{200\ 000} \times 100 = 90\ \%$

2 eff = $\frac{1200}{1500} \times 100 = 80\ \%$

3 The useful output cannot be more than the input: energy cannot be made. Some energy is always wasted, so efficiency is always less than 100 %.

3 Saving energy and resources

1 10 × 60 = 600 W; 10 × 8 = 80 W; 600 − 80 = 520 W less.

2 e.g. loft insulation traps air, which is a poor conductor, so less heat escapes through the roof; double glazing has a gap between two panes that reduces heat loss through windows; cavity wall insulation fills the gap between walls; draught excluders stop warm air escaping under doors. Less heat lost means the heating needs to supply less energy.

3 Much of our electricity is still generated by burning fossil fuels (such as gas). Using less electricity means less fuel needs to be burned, so supplies last longer (and less carbon dioxide is released).

Practical 4: Efficiency of an electric motor

Variables: change the mass lifted (kg); measure the input energy (J) and work out the efficiency (%); keep the same: height lifted, motor, supply voltage, string and axle, starting position.

Prediction, e.g. the efficiency increases as the mass increases, because a bigger share of the input energy goes into lifting the load (or a sensible alternative with a reason).

Equipment: motor, masses and string, clamp stand, joulemeter, power supply, metre stick. Not needed: thermometer.

Hazards, e.g. clamp stand toppling (clamp to bench, keep the base on the bench); string snapping (do not overload, check knots); motor getting hot (switch off between runs); trailing leads (tidy).

Method key points: clamp motor at bench edge; tie the mass to string wound on the axle; measure 0.80 m height with metre stick; reset joulemeter; switch on and lift the mass from the floor tray to the mark, then switch off; record energy; repeat 3 times per mass; 5 masses; Ep = m g h; efficiency = Ep ÷ average input × 100.

Headings: Mass (kg), Useful energy Ep (J), Input 1, 2, 3 (J), Average input (J), Efficiency (%).

Sample results: 0.100 kg 7.8 J, 10 %; 0.200 kg 9.9 J, 16 %; 0.300 kg 11.8 J, 20 %; 0.400 kg 14.4 J, 22 %; 0.500 kg 17.6 J, 22 %.

Graph: mass (kg) on the x axis, efficiency (%) on the y axis, even scales, smooth curve rising and then levelling off.

Conclusion: as the mass lifted increased, the efficiency increased, then levelled off at about 22 %.

Explain: the wasted energy goes mostly as heat in the motor's coils and through friction in the axle and bearings, and some as sound.

Evaluate: (a) the mass is moving and you must react when it reaches the mark, so it may go too high or too low; the input reading is then too big or too small. (b) e.g. more repeats and average; have a marker or stop at the top; use a bigger height so timing errors matter less; reset the joulemeter each time; let the motor cool between runs.

Check-up

1 (a) 300 − 120 = 180 J. (b) eff = $\frac{120}{300} \times 100 =$ 40 %.

2 eff = $\frac{1.6}{2.0} \times 100 = 80\ \%$ (or 1600 ÷ 2000 × 100).

3 Any two: loft insulation, cavity wall insulation, double glazing, draught excluders, turn thermostat down, close doors and curtains, carpets.

4 More of its input energy becomes light and much less is wasted as heat.

TEACHER NOTES

Practical 5: How strong is an electromagnet?

Time	One 50-minute lesson in pairs or threes, plus time to finish the graph and evaluation.
Kit per group	Low-voltage d.c. supply (or a 3 V battery pack), switch, ammeter, leads with crocodile clips, about 1.5 m of PVC-insulated copper wire (about 0.5 mm), a large iron nail (about 7 cm), a pot of identical small steel paperclips.
Prep	Test that a 10-turn coil at about 2 V holds 2 or 3 paperclips. Strip about 1 cm at each wire end. Learners wind the wire neatly in one direction and add 10 turns at a time.
Expected results	The number of clips rises roughly in proportion to the turns, about one extra clip for every 4 turns at 0.8 A. Results vary by ±1 clip between trials, so averages matter. Fewer clips than expected usually means the current dropped or the coil was loose.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages and draws a line graph with their own scales.

Safety and inclusion

- Low voltage only. The coil is close to a short circuit, so it warms up: switch off between readings and keep the current below about 1 A.
- Take care with the nail point. Pick up dropped paperclips.
- Learners with weaker fine motor skills can work the switch, adjust the supply or record; wind coils for them in advance if needed.
- Follow your school and local authority guidance on practical work.

Common problems

- **Current not the same:** a longer coil has more resistance, so the current falls. Adjust the supply to keep the ammeter reading the same.
- **Nail stays magnetised:** a steel nail can keep some magnetism. Use iron, and tap the nail before each test.
- **Clips hung as a chain vs side by side:** agree one method at the start.

No lab, no time, or a learner absent?

The practical includes sample results, so learners can still complete the averages, graph, conclusion and evaluation.

Assessment link

Gives evidence of planning and carrying out an experiment safely, recording results with repeats and averages, presenting them as a line graph, concluding and evaluating, and links to the electromagnetism key area.

Answers: Topic 5

Topic 5: Magnets and electromagnets (N4)

1 Magnets and magnetic fields

1 repel; attract.

2 iron, steel, nickel.

3 At the poles (the ends). The field lines are closest together there.

2 Electromagnets

1 They fall off. With no current there is no magnetic field round the coil, so the iron nail is no longer magnetised.

2 Any two: more turns on the coil; a bigger current (higher supply voltage); use an iron core (if not already).

3 Permanent magnet or electromagnet?

1 An electromagnet can be switched off so the crane can drop the scrap where it wants. A permanent magnet could not let go (and its strength cannot be changed).

2 With no current, the electromagnets stop holding the doors, so the doors swing shut. This stops fire and smoke spreading, and it still works if the fire damages the wiring (fail-safe).

3 an electromagnet; small.

Practical 5: How strong is an electromagnet?

Variables: change the number of turns on the coil; measure the number of paperclips held; keep the same: current (supply voltage), nail, type of wire, size of paperclips, how the clips are added.

Prediction, e.g. the more turns, the more paperclips it holds, because more turns make a stronger magnetic field.

Equipment: low-voltage supply, insulated wire, iron nail, paperclips, ammeter, switch (and leads). Not needed: stopwatch.

Hazards, e.g. sharp point of the nail (point it away, take care when winding); short circuit or loose bare ends (check connections before switching on, use low voltage); paperclips falling on the floor (tidy up, they are a slip hazard).

Method key points: wind 10 turns, connect in series with the switch and ammeter, set the same current each time; switch on, hang paperclips one at a time until no more will stay; record the number held; switch off; repeat 3 times; add 10 turns at a time up to 50.

Headings: Number of turns, Trial 1, 2, 3 (paperclips), Average (paperclips).

Sample averages: 10 turns 2.3; 20 turns 5.3; 30 turns 8.3; 40 turns 11.0; 50 turns 13.7 paperclips.

Graph: number of turns on the x axis, average number of paperclips on the y axis, even scales, straight line of best fit (close to the origin).

Conclusion: as the number of turns increased, the number of paperclips held increased (roughly steadily), so the electromagnet got stronger.

Explain: each turn of wire carrying a current adds to the magnetic field, so more turns make a stronger field and a stronger magnet.

Evaluate: (a) the current also changes the strength, so it must be kept the same for a fair test. (b) e.g. use a newton meter or a balance to measure the force or mass held; use smaller clips or iron filings; more repeats; more turns values.

Check-up

1 Lines leave the N pole and curve round to the S pole on both sides, closer together near the poles, with arrows from N to S. Lines must not cross.

2 It stops being magnetic (it loses its magnetic field).

3 More turns of wire; a bigger current; an iron core.

4 If the power fails there is no current, so the electromagnet lets go and springs put the brake on. The lift stops in its safe state.

5 e.g. permanent: fridge magnet, compass, loudspeaker; electromagnet: scrapyard crane, relay, electric bell, fire door holder, maglev.

TEACHER NOTES

Practical 6: Generating a voltage

Time	One 50-minute lesson in pairs or threes, plus time to finish the graph and evaluation.
Kit per group	Plastic or card tube (about 3 cm wide), about 10 m of thin enamelled or PVC-insulated wire (or ready-made coils), a strong bar or cylinder magnet that falls freely through the tube, data logger with a voltage sensor (or a sensitive centre-zero meter), clamp and stand, soft pad.
Prep	Set the logger to sample fast (at least 100 times a second) and to show the highest reading. Learners wind 50 turns at a time in the same direction, near the middle of the tube.
Expected results	The peak voltage is roughly proportional to the number of turns, tens of millivolts for 50 turns. Trials vary by a few mV. A straight line through the origin is a good outcome. A dropped magnet gives one pulse one way, then one the other way as it leaves the coil.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages and draws a line graph with their own scales.

Safety and inclusion

- Strong (neodymium) magnets can pinch skin and shatter if they snap together. Keep them apart and use a soft pad below the tube.
- Keep magnets away from phones, bank cards and pacemakers.
- Learners can work seated. A learner who finds winding hard can drop the magnet or read the logger; pre-wound coils of 50 to 250 turns work well.
- Follow your school and local authority guidance on practical work.

Common problems

- **Tiny or no readings:** check the wire ends are stripped and the logger range is in millivolts.
- **Using a slow voltmeter:** the pulse is too quick to read. Push the magnet in and out by hand with a centre-zero meter for a qualitative version.
- **Speed changes:** drop from a marked height; do not throw the magnet.

No lab, no time, or a learner absent?

The practical includes sample results, so learners can still complete the averages, graph, conclusion and evaluation.

Assessment link

Gives evidence of planning and carrying out an experiment safely, recording results with repeats and averages, presenting them as a line graph, concluding and evaluating, and links to the generation of electricity and transformers key area.

Answers: Topic 6

Topic 6: Transformers and the National Grid (N4)

1 Generating a voltage

1 Zero. A voltage is only made while the magnet (or coil) is moving.

2 Move the magnet faster; use more turns on the coil; use a stronger magnet.

3 fast; faster.

2 The National Grid

1 $\frac{40}{2.5}$ = 16 times smaller.

2 At a high voltage the current in the cables is much smaller for the same power, so much less energy is lost as heat in the cables.

3 400 000 V would be extremely dangerous in homes; appliances are designed for 230 V.

3 Transformers

1 $Vs = Vp \times \frac{ns}{np} = 6 \times 2000 \div 100$; Vs = 120 V.

2 $\frac{ns}{np} = \frac{Vs}{Vp}$; ns = 500 × 400 000 ÷ 25 000; ns = 8000 turns.

Practical 6: Generating a voltage

Variables: change the number of turns on the coil; measure the highest voltage (mV); keep the same: magnet, drop height (speed), tube, type of wire, position of the coil on the tube.

Prediction, e.g. the more turns, the bigger the voltage, because each turn adds to the voltage made.

Equipment: plastic tube, insulated wire, strong magnet, data logger (or sensitive voltmeter), metre stick. Not needed: paperclips, thermometer.

Hazards, e.g. magnet falling onto the floor or feet (soft pad underneath, catch it); strong magnet near phones or bank cards (keep them away); trailing leads (tidy them).

Method key points: wind 50 turns round the tube, connect to the data logger; drop the magnet from 10 cm above the tube, record the highest voltage; repeat 3 times; add 50 turns at a time up to 250.

Headings: Number of turns, Trial 1, 2, 3 (mV), Average (mV).

Sample averages: 50 turns 20.7 mV; 100 turns 41.3 mV; 150 turns 61.3 mV; 200 turns 80.7 mV; 250 turns 101.0 mV.

Graph: number of turns on the x axis, average voltage (mV) on the y axis, straight line through (or close to) the origin.

Conclusion: as the number of turns increased, the voltage increased (it roughly doubles when the turns double).

Explain: a voltage is made in each turn as the magnet moves through it; the voltages of all the turns add together.

Evaluate: (a) the speed of the magnet affects the voltage, so the height must be the same for a fair test. (b) drop the magnet from different heights (higher means faster), keeping the turns the same; or push the magnet through at different speeds.

Check-up

1 Connect the coil to a meter (complete circuit). Move the magnet into or out of the coil (or move the coil). While it moves, a voltage is made; holding still makes no voltage.

2 To increase the voltage so that the current in the transmission lines is small, which reduces the energy lost as heat in the cables.

3 $Vs = Vp \times \frac{ns}{np} = 230 \times 48 \div 920$; Vs = 12 V.

4 Step-down: there are fewer turns on the secondary coil than the primary, so the output voltage is smaller.

TEACHER NOTES

Practical 7: Testing the circuit rules

Time	One 50-minute lesson in pairs, plus time to finish the bar chart and evaluation.
Kit per group	3 V battery pack (two 1.5 V cells) or a low-voltage supply, two identical 2.5 V lamps in holders, about 8 leads, a digital ammeter (0–2 A range) and a digital voltmeter (0–20 V range), switch. Multimeters are fine if learners are shown which sockets to use.
Prep	Check the lamps match and the meters read zero. Give each pair a printed copy of both circuit diagrams so they can tick off each reading point.
Expected results	Series: about 0.15 A at every point, about 1.5 V across each lamp. Parallel: about 0.23 A in each branch, about 0.46 A from the supply, about 2.9 V across each lamp. The battery voltage drops a little when the parallel circuit draws more current.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages and presents results as a bar chart with their own scale.

Safety and inclusion

- Low voltage only. Never connect an ammeter directly across the battery: it acts as a short circuit and the wires get hot.
- Lamps get hot. Switch off and let them cool before changing them.
- Coloured leads (red to +) help learners who find diagrams hard. One learner builds, one checks against the diagram and one records; everything can be done seated.
- Follow your school and local authority guidance on practical work.

Common problems

- **Ammeter in parallel:** the lamps go out or dim. Remind learners to break the circuit and put the ammeter in the gap.
- **Negative readings:** the meter leads are the wrong way round. Swap them over.
- **Branch currents not quite adding up:** a good evaluation point (meter resolution, battery running down, contact resistance).

No lab, no time, or a learner absent?

The practical includes sample results, so learners can still complete the averages, bar chart, conclusion and evaluation.

Assessment link

Gives evidence of planning and carrying out an experiment safely, recording results with repeats and averages, presenting them as a chart, concluding and evaluating, and links to the practical electrical circuits key area.

Answers: Topic 7

Topic 7: Series and parallel circuits (N4)

1 Circuit symbols

1 a solar cell; b fuse; c LDR (light dependent resistor); d relay.

2 e.g. it uses much less energy so the battery lasts longer; it lasts longer; it is tougher (no filament to break).

2 Measuring current and voltage

1 series; across.

2 A2 = 0.3 A; A3 = 0.3 A (current is the same everywhere in series); V2 = 9 − 4 = 5 V.

3 Parallel circuits

1 A = 0.5 + 1.5 = 2.0 A; V1 = 12 V; V2 = 12 V.

2 Any two: each light can be switched on and off by itself; if one bulb fails the others stay on; each light gets the full mains voltage (230 V).

Practical 7: Testing the circuit rules

Variables: change how the lamps are connected (series or parallel); measure the current at each point (A) and the voltage across each lamp and the supply (V); keep the same: battery pack, the two lamps, the meters, the leads.

Prediction, e.g. in series the current is the same everywhere; in parallel the branch currents add up to the supply current.

Equipment: battery pack, two lamps (in holders), leads, ammeter, voltmeter (a switch is useful). Not needed: magnet, thermometer.

Hazards, e.g. short circuit makes wires and the battery hot (check the circuit before connecting, never connect an ammeter straight across the battery); a lamp bulb breaking (handle gently, tell the teacher); trailing leads (keep the bench tidy). Low voltage only, never mains.

Method key points: build the series circuit; put the ammeter at A1, read, then move it to A2 and A3; connect the voltmeter across L1, L2 and the battery; build the parallel circuit and measure A, A1, A2, V1, V2 and the supply; disconnect, reconnect and repeat; average.

Headings: A1 (A), A2 (A), A3 (A), V1 (V), V2 (V), Supply (V); for parallel A (A), A1 (A), A2 (A), V1 (V), V2 (V), Supply (V).

Sample averages. Series: A1 0.15 A, A2 0.145 A (0.15 A), A3 0.15 A; V1 1.475 V, V2 1.465 V, supply 2.945 V (1.48 V, 1.47 V, 2.95 V to 2 d.p.). Parallel: A 0.455 A, A1 0.225 A, A2 0.23 A; V1 2.875 V, V2 2.88 V, supply 2.885 V.

Bar chart: the three series currents are the same height (about 0.15 A); in parallel, A (about 0.46 A) is roughly the sum of A1 and A2 (about 0.23 A each).

Conclusion: in series the current is the same at every point and V1 + V2 = supply voltage (1.48 + 1.47 = 2.95 V). In parallel A1 + A2 = A (0.23 + 0.23 = 0.46 A) and the voltage across each lamp equals the supply voltage (about 2.9 V).

Explain: yes, within the accuracy of the meters (small differences of 0.01 are rounding/meter errors).

Evaluate: (a) meters only read to 0.01, readings change as the battery runs down, leads and connections have some resistance, lamps are not exactly identical. (b) e.g. use a fresh battery or a power supply; use more sensitive meters; take more repeats and average; use the same meter for every reading.

Check-up

1 Lamp: circle with a cross; cell: long thin line and short thick line; resistor: rectangle; voltmeter: circle with V; LED: diode (triangle and bar) with two arrows pointing out.

2 Ammeter: in series with the lamp (in the same loop). Voltmeter: in parallel, across the lamp (one lead on each side).

3 12 − 7.5 = 4.5 V.

4 0.4 + 0.6 = 1.0 A.

5 e.g. if one bulb fails, the others still work (important for safety); each lamp gets the full 12 V; each can be switched separately.

TEACHER NOTES

Practical 8: Does a longer wire have more resistance?

Time	One 50-minute lesson in groups of 2 or 3, plus time to complete the analysis.
Kit per group	1 m of constantan resistance wire (about 0.3 mm diameter, 32 swg, roughly 8 Ω per metre) taped along a metre stick; 1.5 V cell in a holder or a low-voltage supply set to 1.5 to 2 V; switch; ammeter (0 to 1 A) and voltmeter (0 to 5 V) or two digital multimeters; 4 leads, 2 crocodile clips.
Prep	Tape the wire down at both ends and fold the sharp ends under the tape. Check the meters read zero and the cells are fresh. Test one set of readings at 50 cm.
Expected results	Resistance is directly proportional to length: about 1.6 Ω at 20 cm up to about 8 Ω at 100 cm. Voltage readings rise slightly at longer lengths because the cell has its own internal resistance; this is why learners calculate R from V and I rather than assuming the voltage is fixed.
Ohmmeter option	A multimeter on the 200 Ω range can measure the resistance directly (circuit disconnected). Readings include about 0.1 to 0.3 Ω from the leads, which is a good evaluation point.

Safety and inclusion

- Low voltage only. Short lengths draw larger currents and get hot: keep lengths at 20 cm or more, switch off between readings, and do not touch the wire while the current flows.
- Learners who find connecting clips hard can read the meters or record. Digital meters are easier to read than analogue ones.
- Follow your school and local authority guidance on practical work.

Common problems

- **Meters in the wrong place:** the voltmeter must be across the clips only, not across the whole circuit. The ammeter goes in the main loop.
- **Poor contact:** clips on the wire's enamel or loose clips give jumpy readings. Press the clip firmly onto bare wire.
- **Units:** lengths in cm are fine for the graph. Remind learners to change mA to A if their meter reads in mA.

No lab, no time, or a learner absent?

The sample results let learners calculate resistance, find averages, draw the graph and complete the conclusion and evaluation.

Assessment link

Gives evidence of planning an experiment, recording results with repeats and averages, presenting them as a line graph, drawing a conclusion and evaluating, and of using V = IR in a practical context.

Answers: Topic 8

Topic 8: Resistance and V = IR (N4)

1 What is resistance?

1 The ohm, symbol Ω.

2 series; parallel.

3 The 10 Ω resistor. It has less resistance, so it opposes the current less and (with the same battery voltage) a bigger current flows.

2 The relationship V = IR

1 0.5 A; 0.02 A; 1.5 A; 0.075 A

2 V = I R; V = 2.0 × 6.0; V = 12 V.

3 $R = \frac{V}{I}$; $R = \frac{12}{4.0}$; R = 3.0 Ω.

3 Resistors in series and resistance of a wire

1 R_T = 15 + 25 = 40 Ω.

2 more; less.

3 The shower takes a much larger current. A thick cable has a lower resistance, so it does not overheat; a thin cable would get hot and could cause a fire. A lamp takes a small current so a thin cable is safe.

Practical 8: Does a longer wire have more resistance?

Variables: change the length of wire between the clips (cm); measure voltage (V) and current (A) and calculate resistance (Ω); keep the same: the wire (same material and thickness), the battery or supply voltage, the same meters, temperature of the wire (switch off between readings).

Prediction, e.g. the longer the wire, the greater its resistance, because the current has further to travel through the wire.

Equipment: battery (or low-voltage supply), switch, ammeter, voltmeter, resistance wire on a metre stick, leads with crocodile clips. Thermometer and stopwatch not needed.

Hazards, e.g. the wire getting hot at short lengths (switch off between readings, keep lengths at 20 cm or more); sharp wire ends (tape them down); using the mains (only use a battery or low-voltage supply).

Method key points: ammeter in series, voltmeter across the length of wire being tested; clip at 0 cm, second clip at 20 cm; switch on, read V and I, switch off; move the clip to 40, 60, 80, 100 cm; $R = \frac{V}{I}$; repeat each length three times and average.

Headings: Length (cm), Voltage (V), Current (A), Run 1, 2, 3 resistance (Ω), Average resistance (Ω).

Sample run 1: 1.6, 3.2, 4.8, 6.5, 8.1 Ω. Averages: 20 cm 1.6 Ω; 40 cm 3.2 Ω; 60 cm 4.8 Ω; 80 cm 6.4 Ω; 100 cm 8.0 Ω.

Graph: length (cm) on the x axis, average resistance (Ω) on the y axis, even scales, straight line of best fit through (or very near) the origin.

Conclusion: as the length of the wire increased, its resistance increased. Doubling the length doubled the resistance (about 8 Ω per metre).

Explain: a longer wire gives more material for the current to pass through, so there is more opposition to the current.

Evaluate: (a) resistance goes up as the wire heats up, so readings change while the current is on; switch off between readings and take readings quickly, or use a lower voltage. (b) e.g. more repeats; more lengths; check the clips are at exactly the right marks and make good contact; use digital meters with more decimal places.

Check-up

1 V = I R; V in volts (V), I in amperes (A), R in ohms (Ω).

2 I = 20 mA = 0.020 A; V = I R = 0.020 × 150; V = 3.0 V.

3 $I = \frac{V}{R}$; $I = \frac{230}{46}$; I = 5.0 A.

4 R_T = 33 + 47 + 100 = 180 Ω.

5 The thick wire has the lower resistance. Use it for the cooker: the cooker takes a large current, and a thick (low resistance) cable will not overheat.

TEACHER NOTES

Practical 9: Light level and an LDR

Time	One 50-minute lesson in groups of 2 or 3, plus time to complete the analysis.
Kit per group	Desk lamp or ray box (an LED bulb stays cool), LDR on a small block or in a holder, digital multimeter on the 20 kΩ range (or a 6 V battery, ammeter and voltmeter to calculate $R = \frac{V}{I}$), two leads with crocodile clips, metre stick. Optional: a short black card tube to shield the LDR.
Prep	Check the multimeters have batteries and are set to ohms. Darken the room as much as you safely can and space groups apart so their lamps do not affect each other. Test one LDR: readings should change clearly when you cover it with a hand.
Expected results	Values depend on the LDR and lamp. With a typical LDR and desk lamp, expect a few hundred ohms at 10 cm rising to a few kilohms at 50 cm. The curve rises more and more steeply because the light level falls off quickly with distance.
Link to theory	Connect the result to the street lamp and the night light on the logic gates page: the LDR is the input, and its big change in resistance lets the process tell light from dark.

Safety and inclusion

- Filament bulbs and shades get very hot: use LED bulbs where possible and move the LDR, not the lamp. Keep mains cables tidy and away from water.
- In a darkened room keep exits clear and bags off the floor. Learners who dislike the dark can use the card tube method with the lights on.
- Learners who find handling small parts hard can read the meter or record. Follow your school and local authority guidance on practical work.

Common problems

- **Stray light:** readings at 40 to 50 cm are very sensitive to windows, other lamps and shadows from people. This is a key evaluation point.
- **Meter range:** if the display shows 1 or OL, switch to a higher range. Remind learners to write the unit (Ω or kΩ) and convert kΩ to Ω.
- **Measuring distance:** agree a fixed point (front of the bulb to the face of the LDR).

No lab, no time, or a learner absent?

The sample results let learners find averages, draw the graph and complete the conclusion and evaluation.

Assessment link

Gives evidence of planning an experiment, recording results with repeats and averages, presenting them as a line graph, drawing a conclusion and evaluating, and links to input devices in electronic systems.

Answers: Topic 9

Topic 9: Electronic systems (N4)

1 Input, process, output

1 Input: the sensor that detects hands (e.g. a light sensor). Output: the heater and the fan (motor).

2 digital; analogue.

3 No. The bulb (lamp) is the output. The process is the part that decides to switch the lamp on when the light sensor detects it is dark.

2 Input and output devices

1 Microphone; thermistor (temperature sensor); LDR (light sensor).

2 To limit the current. Too large a current would damage (burn out) the LED.

3 Its resistance increases (rises) as the light level falls.

3 Logic gates

1 Alarm sounds: 0, 0, 0, 1 (only when the door is open and it is dark). It is an AND gate.

2 An OR gate.

3 A NOT gate: it gives 1 (lamp on) when the sensor gives 0 (dark).

Practical 9: Light level and an LDR

Variables: change the distance from the lamp to the LDR (cm); measure the resistance of the LDR (Ω); keep the same: the lamp and its brightness, the LDR, the room lighting (darkened), the LDR facing the lamp, the multimeter range.

Prediction, e.g. the further the LDR is from the lamp, the higher its resistance, because less light reaches it.

Equipment: lamp, LDR, multimeter (set to ohms), metre stick, leads with clips. Thermometer and balance not needed.

Hazards, e.g. trailing mains cable from the lamp (keep it tidy, away from the edge and water); moving around in a darkened room (clear bags from floor, leave some light on near exits); hot bulb (LED bulb, do not touch).

Method key points: lamp and LDR at the same height, LDR facing the lamp; measure from the bulb to the LDR with the metre stick; read the resistance on the ohms range; move the LDR to 10, 20, 30, 40, 50 cm; darken the room or shield the LDR with a tube; repeat each distance three times and average.

Headings: Distance (cm), Trial 1, 2, 3 (Ω), Average resistance (Ω).

Sample averages: 10 cm 402 Ω; 20 cm 1063 Ω; 30 cm 1867 Ω; 40 cm 2787 Ω; 50 cm 3813 Ω.

Graph: distance (cm) on the x axis, average resistance (Ω) on the y axis, even scales, smooth curve rising more and more steeply.

Conclusion: as the distance from the lamp increased, the resistance of the LDR increased.

Explain: further from the lamp, the light spreads out so less light reaches the LDR. The resistance of an LDR goes up as the light level goes down.

Evaluate: (a) extra light would make the resistance lower than it should be, especially at large distances; darken the room, close blinds or put the LDR in a black tube facing the lamp. (b) The resistance changes a lot between bright and dim light, so the process can easily detect when it gets dark and switch the lamp on.

Check-up

1 Input: heat sensor. Process: logic circuit. Output: siren.

2 An analogue signal can have any value and changes smoothly. A digital signal has only two values, on (1) or off (0).

3 Q: 0, 1, 1, 1.

4 A NOT gate on the belt sensor (gives 1 when the belt is not fastened) and an AND gate combining this with the engine signal, so the buzzer sounds only when the engine is on and the belt is not fastened.

5 Movement: motor. Sound: loudspeaker (or buzzer).

TEACHER NOTES

Practical 10: Heating trapped air

Time	One 50-minute lesson, plus time to complete the analysis. Best as a teacher-led class practical or in groups of 3 with the teacher adding all hot water.
Kit per group	250 ml round-bottomed flask with a one-holed bung, short thick-walled rubber tube, Bourdon pressure gauge reading in kPa (total pressure), large beaker or plastic tank as a water bath, thermometer, stirring rod, clamp stand. Teacher: kettle and jug.
Prep	Check flasks for cracks and test that each bung and tube holds pressure. Fit the bung before the flask goes into the water. Start with cold tap water (about 15 to 20 °C).
Expected results	Pressure rises steadily by about 3.4 kPa for every 10 °C, from about 101 kPa at 20 °C to about 115 kPa at 60 °C. The graph is a straight line which does not pass through the origin on a Celsius scale. Gauges with 2 kPa divisions give rougher data: repeats help.
Syringe option	Connect a sealed 60 ml syringe to the gauge and push the plunger in steps of 5 ml. Pressure rises as the volume falls. This works with no hot water at all.

Safety and inclusion

- Only the teacher handles the kettle and hot water. Keep the bath below 70 °C, stand the beaker on a stable base and never carry it when hot. Wear eye protection and clamp the flask.
- Learners who find reading scales hard can read the digital thermometer, or record. The syringe option suits seated learners and those who should avoid hot water.
- Follow your school and local authority guidance on practical work.

Common problems

- **Leaks:** the pressure creeps back down. Wet the bung, push it in firmly, and check the tube joints.
- **Reading too soon:** the air lags behind the water temperature. Stir, then wait 2 to 3 minutes.
- **Gauge zero:** most school gauges read total pressure (about 100 kPa in the room); some read the extra pressure above air pressure. Check before the lesson.

No lab, no time, or a learner absent?

The sample results let learners find averages, draw the graph and complete the conclusion and evaluation.

Assessment link

Gives evidence of planning an experiment safely, recording results with repeats and averages, presenting them as a line graph, drawing a conclusion and evaluating, and of using the kinetic model.

Answers: Topic 10

Topic 10: Gases and the kinetic model (N4)

1 The kinetic model of a gas

1 fast; random; far apart.

2 The air particles move fast in random directions and keep colliding with the inside of the ball. Each collision pushes outwards on the ball; together they make the pressure.

3 Gas particles are far apart with lots of space between them, so they can be pushed closer together. In a solid the particles are already touching (packed closely), so it cannot be squashed.

2 Pressure, volume and temperature

1 slower; goes down.

2 The gas cools, so the particles move more slowly. They hit the inside of the balloon less hard and less often, so the gas takes up less volume and the balloon shrinks.

3 The pressure increases. The same particles are squashed into a smaller volume, so they hit the walls more often.

3 Gases in everyday life

1 Air pressure outside falls as the balloon rises. The gas inside pushes out more than the air outside pushes in, so the gas expands and the balloon gets bigger (until it bursts).

2 Driving heats the air in the tyres, which raises the pressure. A reading taken straight after a journey would be too high, so the tyre might be left under-inflated once it cools.

3 Heating makes the gas particles move faster and hit the walls harder and more often, so the pressure rises a lot. The can could burst (explode) and hurt someone.

Practical 10: Heating trapped air

Variables: change the temperature of the water (and so the air) (°C); measure the pressure of the air (kPa); keep the same: the mass of air (bung tight, no leaks), the volume of the flask, the same gauge, the length of tubing.

Prediction, e.g. as the temperature increases the pressure increases, because the particles move faster and hit the walls harder and more often.

Equipment: flask and bung, pressure gauge with short tubing, large beaker (water bath), thermometer, kettle (teacher only). Ammeter and metre stick not needed.

Hazards, e.g. glass flask breaking (check for cracks, clamp it, wear eye protection); spilled water on the floor (mop it up, slip hazard); hot glass and water after the test (let it cool before handling).

Method key points: flask fully under water, bung tight, short tube to the gauge; start with cold water and read temperature and pressure; teacher adds hot water to raise the temperature about 10 °C; stir and wait about 3 minutes so the air reaches the water temperature; read both again; continue up to 60 °C; repeat the whole experiment and average.

Headings: Temperature (°C), Run 1, 2, 3 (kPa), Average pressure (kPa).

Sample averages: 20 °C 101.3; 30 °C 104.3; 40 °C 107.7; 50 °C 111.3; 60 °C 114.7 kPa.

Graph: temperature (°C) on the x axis, average pressure (kPa) on the y axis, scale starting near 100 kPa, straight line of best fit (rising about 3.4 kPa every 10 °C).

Conclusion: as the temperature of the air increased, its pressure increased (steadily).

Explain: the air particles move faster when they are hotter, so they hit the walls of the flask harder and more often, giving a bigger pressure.

Evaluate: (a) the air in the flask takes time to reach the temperature of the water; reading too early gives a pressure that is too low. (b) Air in the tube stays cooler, so the measured pressure is a little lower than it should be. Use a shorter, thinner tube, or put more of the tube under the water.

Check-up

1 A gas is made of tiny particles that are far apart and move very fast in random directions, colliding with each other and with the walls of their container.

2 The pressure decreases. The air cools, so the particles move more slowly and hit the walls less hard and less often.

3 As she rises, the water pressure on her falls, so the air in her lungs expands. Breathing out lets the extra air escape so her lungs are not damaged.

4 The air pressure in the cabin is lower than at the ground (where the packet was sealed). The gas inside the packet pushes out more than the cabin air pushes in, so the packet expands.

5 more often; increases.

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.