REAL-LIFE PHYSICS

Dynamics and Space

Teacher guide

For the National 4 Physics workbook



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Blewis LEARNING

Using the workbooks

The National 4 Physics workbook for **Dynamics and Space** has nine 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.

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TEACHER NOTES

Practical 1: How fast does a trolley roll?

Time	One 50-minute lesson. Groups of three: one releases, one times, one records.
Kit per group	Dynamics trolley (or a toy car), ramp or board about 1.2 m long, books or blocks, metre stick, masking tape, stopwatch or phone timer, a soft stop at the bottom (bag or block).
Prep	Check trolleys run straight. Mark a start line and a finish line 1.00 m further down each ramp. Clear floor space at the end of each bench.
Expected results	With a 1.2 m ramp and 1.00 m between the lines, times fall from about 2.4 s (5 cm high) to about 1.1 s (25 cm). Average speed rises from about 0.4 m/s to about 0.9 m/s, levelling off a little as the ramp gets steeper.
Along a bench	If ramps are short, give the trolley a gentle push along a bench and time it between two lines 1.00 m apart. Compare different pushes, or a trolley with and without a cloth under it.

Safety and inclusion

- Keep ramp heights low and secure the ramp so it cannot slide off the books. Always use a stop at the bottom.
- Catch the trolley from the side, not in front, to avoid trapped fingers. Keep bags and cables off the floor.
- Every role can be done seated. Learners who find fine timing hard can release the trolley or record, and swap roles between heights.
- Follow your school and local authority guidance on practical work.

Common problems

- **Pushing on release:** the trolley must start from rest. Hold it with a ruler at the start line and lift the ruler away.
- **Reaction time:** start and stop errors of about 0.1–0.2 s are large compared with times of 1–2 s. Discuss this in the evaluation and link it to light gates in Topic 2.
- **Forgetting the units step:** heights in cm are fine for the graph, but the distance in $v = d \div t$ should be 1.00 m.

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 an experiment, recording results with repeats and averages, presenting them as a line graph, drawing a conclusion and evaluating, and of using $d = v\,t$ in a practical context.

Answers: Topic 1

Topic 1: Speed, distance and time (N4)

1 What is speed?

1 m/s, km/h, mph

2 3 m/s

3 $\frac{56}{5}$ = about 11 times faster.

4 Yes. 13 m/s is 13 metres every second, which is about 47 km/h. 13 km/h is only 13 000 m in a whole hour (about 3.6 m/s).

2 The speed relationship

1 d = v t = 1.5 × 80 = 120 m

2 v = $\frac{d}{t}$ = $\frac{600}{50}$ = 12 m/s

3 Getting the units right

1 180 s; 600 s; 90 s; 7200 s; 2500 m

2 t = 10 × 60 = 600 s; v = $\frac{1800}{600}$ = 3.0 m/s

3 d = 4.5 km = 4500 m; t = $\frac{d}{v}$ = $\frac{4500}{5.0}$ = 900 s

Practical 1: How fast does a trolley roll?

Variables: change the height of the ramp (cm); measure the time to travel between the lines (s) and so the average speed (m/s); keep the same: distance between the lines, trolley (and its mass), ramp surface, release point, release method (let go, no push), who times.

Prediction, e.g. the higher the ramp, the greater the average speed, because the slope is steeper so the trolley speeds up more.

Equipment: trolley, ramp, books or blocks, metre stick, stopwatch. Not needed: thermometer, balance.

Hazards, e.g. ramp slipping off the books (secure it, keep low heights); trip hazard from trailing kit or bags (clear the floor); trapped fingers when stopping the trolley (catch from the side, use a soft stop).

Method should include: measure height with the metre stick; mark start and finish 1.00 m apart with tape; release from rest at the start (no push); start the stopwatch on release and stop at the finish line; repeat three times for each height; average the times; v = $\frac{d}{t.}$

Headings: Height (cm), Time 1, 2, 3 (s), Average time (s), Average speed (m/s).

Sample averages: 5 cm 2.41 s, 0.41 m/s; 10 cm 1.71 s, 0.58 m/s; 15 cm 1.41 s, 0.71 m/s; 20 cm 1.21 s, 0.83 m/s; 25 cm 1.06 s, 0.94 m/s.

Graph: height (cm) on the x axis, average speed (m/s) on the y axis, even scales, smooth curve rising less steeply as height increases.

Conclusion: as the height of the ramp increased, the average speed of the trolley increased.

Explain: a steeper slope means more of the trolley's weight acts down the slope, so it speeds up more and covers the 1.00 m in less time.

Evaluate: repeats within about 0.1 s show the results are reliable. Improvements: use light gates (no reaction time), make the distance longer so timing errors matter less, have the same person time every run, use more repeats.

Check-up

1 d = v t; d in metres (m), v in metres per second (m/s), t in seconds (s).

2 v = $\frac{d}{t}$ = $\frac{200}{32}$ = 6.25 m/s (6.3 m/s)

3 t = 2 × 60 = 120 s; d = v t = 13 × 120 = 1560 m

4 d = 2100 m; t = $\frac{d}{v}$ = $\frac{2100}{1.4}$ = 1500 s; $\frac{1500}{60}$ = 25 minutes.

5 Any one timing could be wrong (reaction time, a push on release). The average of three is more reliable, and a result that does not fit can be spotted.

TEACHER NOTES

Practical 2: Speed at the bottom of a ramp

Time	One 50-minute lesson. Use the same ramps and start line as Practical 1 so the results can be compared.
Kit per group	Trolley, ramp about 1.2 m long, books or blocks, light gate with timer or data logger and laptop, card 5.0 cm long fixed upright on the trolley, metre stick, a soft stop. No light gates: a phone with slow-motion video, a ruler and tape.
Prep	Cut and fix the cards (measure them accurately). Set the timer to measure the time the beam is blocked. Place the light gate 1.00 m down the ramp from the start line, with the beam at card height.
Expected results	With a 5.0 cm card, times fall from about 0.060 s (5 cm high) to about 0.026 s (25 cm). Speeds rise from about 0.8 m/s to about 1.9 m/s, roughly twice the average speeds from Practical 1, as expected for a trolley speeding up steadily from rest.

Safety and inclusion

- Secure ramps, use a stop after the light gate and tape down cables. Catch the trolley from the side.
- All roles can be done seated. The slow-motion method suits learners who find quick timing hard, and frame counting can be done on a tablet afterwards.
- Follow your school and local authority guidance on practical work.

Common problems

- **Card not blocking the beam fully:** the timer reads nothing or a tiny time. Check the beam height with the trolley held in the gate.
- **Card length in cm:** learners must change 5.0 cm to 0.050 m before dividing.
- **Timer mode:** some loggers give speed directly if told the card length. Ask learners to record the time and calculate anyway.
- **Slow motion:** check the frame rate in the phone settings (often 120 or 240 frames per second).

No lab, no time, or a learner absent?

The sample results let learners complete the speeds, graph, comparison and evaluation without doing the practical.

Assessment link

Gives evidence of planning an experiment, using light gates to measure instantaneous speed, processing repeat results, presenting a line graph, drawing a conclusion and evaluating.

Answers: Topic 2

Topic 2: Average and instantaneous speed (N4)

1 Average or instantaneous?

1 $v = \frac{d}{t} = \frac{100}{14} = 7.1$ m/s

2 Between 6 s and 8 s (40 m to 57 m, 17 m). $v = \frac{17}{2} = 8.5$ m/s.

3 instantaneous; average; instantaneous; average

2 Measuring instantaneous speed

1 d = 10 cm = 0.10 m; $v = \frac{d}{t} = \frac{0.10}{0.25} = 0.40$ m/s

2 It has no human reaction time when starting and stopping the timer, and it measures to 0.001 s.

3 The trolley's speed hardly changes in the short time the card takes to pass, so the result is the speed at that point, not an average over a long distance.

3 Speed checks in real life

1 d = 3000 m; t = 2.5 × 60 = 150 s; $v = \frac{3000}{150} =$ 20 m/s

2 The cameras work out the average speed over the whole distance. If the car drove too fast between them, the time is short and the average speed is still too high.

3 $v = \frac{d}{t} = \frac{8.0}{0.50} = 16$ m/s

Practical 2: Speed at the bottom of a ramp

Variables: change the height of the ramp (cm); measure the time the card blocks the beam (s) and so the instantaneous speed (m/s); keep the same: card length, start line, distance to the light gate, trolley, release from rest.

Prediction, e.g. the higher the ramp, the faster the trolley at the bottom, because it speeds up more on a steeper slope.

Equipment: trolley, ramp, light gate, card, timer or laptop, metre stick. Not needed: thermometer. (Books or blocks to raise the ramp.)

Hazards, e.g. ramp slipping (secure it); trailing light gate cable (tape it down); trapped fingers (catch from the side).

Headings: Height (cm), Time 1, 2, 3 (s), Average time (s), Speed (m/s).

Sample averages and speeds ($v = \frac{0.050}{t}$): 5 cm 0.060 s, 0.83 m/s; 10 cm 0.043 s, 1.16 m/s; 15 cm 0.035 s, 1.43 m/s; 20 cm 0.030 s, 1.67 m/s; 25 cm 0.026 s, 1.92 m/s.

Graph: height (cm) on x axis, speed (m/s) on y axis, smooth rising curve.

Conclusion: as the height of the ramp increased, the instantaneous speed at the bottom increased.

Compare (sample): 5 cm 0.83 m/s; 15 cm 1.43 m/s; 25 cm 1.92 m/s. The speed at the bottom is about twice the average speed, because the trolley starts from rest and speeds up all the way down. The average includes the slow part at the top; the speed at the bottom is the highest speed.

Evaluate: repeats within about 0.002 s show reliable results. Improvements: more repeats, release with a ruler so there is no push, check the card passes straight through the beam, make sure the card length is measured accurately.

Check-up

1 Average speed is the total distance ÷ total time for a whole journey; instantaneous speed is the speed at one particular moment (as shown on a speedometer).

2 d = 0.025 m; $v = \frac{d}{t} = \frac{0.025}{0.020} = 1.25$ m/s (1.3 m/s)

3 d = 6000 m; t = 20 × 60 = 1200 s; $v = \frac{6000}{1200} =$ 5.0 m/s

4 $v = \frac{d}{t} = \frac{4000}{160} = 25$ m/s. 25 m/s is more than 22 m/s, so yes, it was speeding.

TEACHER NOTES

Practical 3: A speed–time graph of a journey

Time	One 50-minute lesson: 25 minutes outside or in a hall, 25 minutes processing and graphing.
Kit	Measuring tape (30 m), 7 cones, 6 stopwatches or phone timers, clipboards. Optional: motion sensor and data logger with a trolley on a ramp, or a learner walking towards a wall-mounted sensor.
Prep	Lay cones every 5 m along a straight, flat 30 m course with run-off space after it. Groups of eight: one walker, six timers, one recorder. Agree a clear "go" signal.
Expected results	Walking about 1.5 m/s, jogging about 3 m/s. Section speeds rise, level off, then fall. The sample data give 1.7, 2.5, 3.1, 3.1, 2.5 and 1.7 m/s.
Smaller groups	With fewer timers, use lap or split mode on one stopwatch run alongside, or film the run from the side against the cones and read times from the video.

Safety and inclusion

- Use a dry, level surface with plenty of space after the finish. Timers stand well to the side.
- Walking only is fine: the pattern can be slow walk, fast walk, slow walk. A learner using a wheelchair can be the "walker" or a timer. A trolley on a ramp with a motion sensor is a fully seated alternative.
- Follow your school and local authority guidance on practical work and working outdoors.

Common problems

- **Using the time at the marker as the section time:** section time is the difference between two marker times.
- **Plotting at the end of a section:** each speed is an average over the section, so plot it at the middle time. Accept end times from weaker learners if they are consistent.
- **Graph through the origin:** remind learners the walker starts from rest, so the graph starts at (0, 0).

No lab, no time, or a learner absent?

The sample results let learners complete the averages, speeds, graph, conclusion and evaluation without going outside.

Assessment link

Gives evidence of planning, collecting and averaging repeat measurements, processing data, drawing a speed–time graph, describing motion and evaluating.

Answers: Topic 3

Topic 3: Speed–time graphs (N4)

1 Reading speed–time graphs

1 Bus waiting: Q; train pulling out: R; car cruising: S; cyclist braking: P.

2 The graph shows speed, not distance. A flat line above zero means the train is moving at a constant (steady) speed. It is only stationary if the line is on the time axis (speed = 0).

2 Describing motion

1 A: speeds up from 0 to 10 m/s in 10 s. B: constant speed of 10 m/s for 20 s. C: speeds up from 10 m/s to 20 m/s in 10 s. D: constant speed of 20 m/s for 20 s. E: slows down from 20 m/s to 0 in 20 s (stops at 80 s).

2 20 m/s

3 20 s + 20 s = 40 s

3 Distance from the graph

1 Triangle ½ × 10 × 6 = 30 m; rectangle 30 × 6 = 180 m; total 210 m.

2 Rectangle 30 × 12 = 360 m; triangle ½ × 20 × 12 = 120 m; total 480 m.

Practical 3: A speed–time graph of a journey

Variables: measure the time at each 5 m marker (s); work out the speed in each section (m/s); keep the same: course length and marker spacing, the same walker, the same pattern of walk, jog, walk, how timers start and stop.

Prediction sketch: line rising from zero, flat at the top, then falling (or levelling at a walking speed).

Equipment: stopwatches, cones, measuring tape, timers (partners); motion sensor if available. Not needed: thermometer, balance.

Hazards, e.g. slipping on a wet or uneven surface (use a dry, flat area, sensible shoes); jogging into obstacles or people (clear the course and the run-off space at the end).

Headings: Distance (m), Run 1, 2, 3 (s), Average time (s).

Sample averages: 5 m 3.0 s; 10 m 5.0 s; 15 m 6.6 s; 20 m 8.2 s; 25 m 10.2 s; 30 m 13.2 s.

Section times: 3.0, 2.0, 1.6, 1.6, 2.0, 3.0 s. Speeds: 1.7, 2.5, 3.1, 3.1, 2.5, 1.7 m/s. Middle times: 1.5, 4.0, 5.8, 7.4, 9.2, 11.7 s.

Graph: time (s) on the x axis, speed (m/s) on the y axis, starting at (0, 0), rising to about 3.1 m/s, level, then falling back to about 1.7 m/s.

Conclusion: the walker sped up at the start, moved at a roughly constant top speed of about 3.1 m/s in the middle (jogging), then slowed down again to walking speed.

Evaluate: (a) any single time could be wrong because of reaction time; the average of three runs is more reliable and odd results can be spotted. (b) Use a motion sensor or light gates (no reaction time), use more markers closer together so the graph shows more detail, practise starting together on a clear signal.

Check-up

1 A: speeds up from 0 to 4 m/s in 4 s. B: constant speed of 4 m/s for 6 s. C: slows down from 4 m/s to 0 in 2 s.

2 4 m/s

3 ½ × 4 × 4 = 8 m; 6 × 4 = 24 m; ½ × 2 × 4 = 4 m; total 36 m.

4 A flat line along the time axis (speed = 0).

TEACHER NOTES

Practical 4: Acceleration down a ramp

Time	One 50-minute lesson in groups of 2 or 3, plus time to complete the analysis.
Kit	Per group: ramp about 1 m long, dynamics trolley, card (about 5 cm wide) fixed on top, two light gates with timer or data logger, metre stick, blocks or books, soft stop. If you have only one gate per group, use a **double-interrupt card** (two flags of known width): one gate measures both speeds and the time between them.
Prep	Check light gates and leads work. Set timers to the mode that gives speed or time blocked. Mark a release line on each ramp. Test one run at 10 cm.
Expected results	For a 1 m ramp, acceleration goes up by roughly 0.1 m/s² for each centimetre of height ($a \approx 9.8 \times \text{height} \div \text{length}$, less friction). Expect about 0.2 to 2.2 m/s² over heights of 5 to 25 cm. The graph is close to a straight line that crosses the height axis just above zero because of friction.
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

- Keep ramps low on the bench and stable. Catch the trolley at the bottom so it does not fall onto feet.
- Tidy leads from light gates so no one trips or pulls kit off the bench.
- Learners who find fine motor tasks difficult can be the timer reader or recorder. Rolling a ball down a gutter works as a simpler version.
- Follow your school and local authority guidance on practical work.

Common problems

- **Pushing the trolley:** gives a starting speed and odd results. Hold it at the mark and let go.
- **Card not cutting the beam:** check the card height lines up with the gate beam.
- **Stopwatch timing:** reaction time is large compared with times under a second. This is a good evaluation point.

No lab, no time, or a learner absent?

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

Assessment link

This practical gives evidence for planning and carrying out an experiment safely, recording and presenting results, drawing a conclusion and evaluating, and links to the acceleration key area of the unit.

Answers: Topic 4

Topic 4: Acceleration (N4)

1 What is acceleration?

1 4, 6, 8 m/s.

2 bigger; small.

3 Decelerating: its speed is going down (by 5 m/s each second).

2 Calculating acceleration

1 $a = \frac{\Delta v}{t}$; $a = \frac{10 - 0}{2.5}$; $a = 4$ m/s².

2 $a = \frac{\Delta v}{t}$; $a = \frac{60}{4}$; $a = 15$ m/s².

3 $a = \frac{\Delta v}{t}$; $a = \frac{14 - 2}{8} = \frac{12}{8}$; $a = 1.5$ m/s².

3 Rearranging and deceleration

1 $\Delta v = a\,t$; $\Delta v = 1.5 \times 4$; $\Delta v = 6$ m/s.

2 $a = \frac{\Delta v}{t}$; $a = \frac{0 - 30}{60}$; $a = -0.5$ m/s², a deceleration of 0.5 m/s².

Practical 4: Acceleration down a ramp

Variables: change the ramp height (cm); measure the acceleration (m/s²); keep the same: trolley and its mass, card length, start position, ramp length and surface, light gate positions.

Prediction, e.g. the higher the ramp, the bigger the acceleration, because the slope is steeper so a bigger force pulls the trolley down it.

Equipment: ramp, trolley, card, two light gates, timer or data logger, metre stick, blocks. Thermometer and measuring cylinder not needed.

Hazards, e.g. heavy ramp or blocks falling (set up on the bench, keep stable); trailing wires (tape down, tuck away); trolley falling off the bench (catch it, soft stop).

Method key points: measure height with metre stick; release trolley from the same mark without pushing; gates measure speed at each gate (card length ÷ time blocked) and time between gates; $a = \frac{v - u}{t}$; repeat 3 times at each height; 5 heights.

Headings: Ramp height (cm), Trial 1, 2, 3 (m/s²), Average (m/s²).

Sample averages: 5 cm 0.24; 10 cm 0.71; 15 cm 1.19; 20 cm 1.66; 25 cm 2.15 m/s².

Graph: x axis ramp height (cm), y axis acceleration (m/s²), even scales, straight line of best fit (it does not pass through the origin because of friction).

Conclusion: as the ramp height increased, the acceleration of the trolley increased (roughly steadily).

Explain: a steeper ramp means a bigger part of the trolley's weight pulls it down the slope, so the unbalanced force is bigger and it speeds up more each second.

Evaluate: (a) light gates time automatically and to a hundredth of a second; human reaction time makes stopwatch timings inaccurate. (b) e.g. more repeats and average, more heights, release with a pin or barrier so there is no push, check the ramp is straight, use a data logger.

Check-up

1 The speed increases by 5 m/s every second.

2 $a = \frac{\Delta v}{t}$; $a = \frac{9 - 3}{4} = \frac{6}{4}$; $a = 1.5$ m/s².

3 $t = \frac{\Delta v}{a}$; $t = \frac{24}{6}$; $t = 4$ s.

4 $a = \frac{\Delta v}{t}$; $a = \frac{2 - 8}{3} = -6 \div 3$; $a = -2$ m/s², a deceleration of 2 m/s².

5 Her reaction time when starting and stopping the stopwatch adds errors, especially for short times.

TEACHER NOTES

Practical 5: Friction on different surfaces

Time	One 50-minute lesson in pairs, plus time to complete the analysis.
Kit	Per pair: 0 to 10 N force meter (a 0 to 5 N meter gives more precise readings on smooth surfaces), wooden block with a hook, 100 g slotted masses (about 500 g in total), four or five surfaces (plastic tray, bench top, carpet tile, sandpaper, rubber mat), sticky tape.
Prep	Cut surfaces to about 50 cm long and tape them to the bench. Zero the force meters held horizontally. Try one block on sandpaper to check the meter range.
Expected results	With about 0.5 kg on the block, readings range from about 1 N (smooth plastic) to about 4 N (rubber). The starting pull is a little higher than the steady sliding force: tell learners to read once the block is moving steadily.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages and draws a bar chart with their own scale.

Safety and inclusion

- Keep stacks of masses small and away from the bench edge. Do not overstretch meters: the spring can snap back.
- Hold sandpaper by its edges. Anyone with a latex allergy should avoid rubber mats unless they are latex free.
- Learners who find a steady pull hard can read the meter while a partner pulls, or pull the block with a string wound on a pencil. Seated work at a low table is fine.
- Follow your school and local authority guidance on practical work.

Common problems

- **Jerky pulling:** the pointer jumps about. Pull slowly and read when it settles.
- **Pulling at an angle:** part of the pull lifts the block. Keep the meter level with the bench.
- **Meter not zeroed when horizontal:** zero it on its side before starting.

No lab, no time, or a learner absent?

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

Assessment link

This practical gives evidence for planning and carrying out an experiment safely, recording and presenting results, drawing a conclusion and evaluating, and links to the forces and Newton's first law key area of the unit.

Answers: Topic 5

Topic 5: Forces and Newton's first law (N4)

1 What forces do

1 Stress ball: shape. Braking: speed. Steering: direction. Kicking a still ball: speed (and shape briefly, accept direction too).

2 3.5 N

3 A bigger force pulls the spring harder, so it stretches further; the stretch is shown on the scale.

2 Balanced forces and Newton's first law

1 A: 0 N, balanced, keeps moving at a constant 20 m/s. B: 30 N (to the right), unbalanced, speeds up to the right. C: 50 N (backwards), unbalanced, slows down. D: 0 N, balanced, stays still.

2 40 N. The box does not move, so the forces are balanced: friction must be equal and opposite to the push.

3 Friction and staying safe

1 Useful, e.g. brakes, grip of tyres or shoes, walking, holding a pen. A problem, e.g. wear in machines or bike chains, heat in engines, air resistance slowing a cyclist or car.

2 The car slows down but no force acts on the passenger, so they keep moving forward at the same speed until they hit the seat in front, dashboard or windscreen.

Practical 5: Friction on different surfaces

Variables: change the type of surface; measure the force needed to pull the block at a steady speed (N); keep the same: block, mass on top, force meter, pulling horizontally, speed of pull.

Prediction, e.g. the rubber mat or sandpaper will give the most friction because they are the roughest or grippiest.

Equipment: force meter, block with hook, masses, test surfaces, sticky tape. Thermometer and measuring cylinder not needed.

Hazards, e.g. sandpaper scratching skin (hold the edges); force meter or block snapping back if pulled too hard (pull gently, stay within the meter's range).

Headings: Surface, Trial 1, 2, 3 (N), Average (N).

Sample averages: plastic 1.0 N; wooden bench 1.7 N; carpet 2.6 N; sandpaper 3.4 N; rubber mat 4.1 N.

Bar chart: surfaces on the x axis, force (N) on the y axis, even scale, bars not touching.

Conclusion: the rubber mat had the most friction and the plastic tray the least; rougher or grippier surfaces need a bigger force.

Explain: rough surfaces have bigger bumps that catch and lock together, so a bigger force is needed to slide the block.

Evaluate: (a) at a steady speed the forces are balanced, so the pull equals the friction; if it speeds up, the reading is too big. (b) e.g. repeat more times and average, pull with a motor or slope for a steadier speed, use a meter with a smaller scale, clean surfaces, use a data logger force sensor.

Check-up

1 Newton (N); force meter (newton balance or spring balance).

2 (a) Balanced. (b) It keeps moving at a constant speed in a straight line.

3 Friction and air resistance act against the motion. There is no forward force, so the unbalanced force is backwards and he slows to a stop.

4 Reduce: oil the chain, pump tyres up, streamlined riding position. Increase: tyres with good tread, brakes, rubber grips.

5 The air bag inflates and the driver's head hits a soft cushion; it slows them over a longer time and spreads the force over a bigger area, so the force on them is smaller.

TEACHER NOTES

Practical 6: Mass and weight

Time	One 50-minute lesson in pairs, including the graph. Quick to set up.
Kit	Per pair: 0 to 10 N newton balance, 100 g mass hanger and slotted masses (600 g in total), clamp stand, boss and clamp, G-clamp or heavy weight for the base. Optional: top-pan balance to check the masses.
Prep	Check the balances read zero when hanging empty, and that they have not been overstretched. Count out masses for each group.
Expected results	Each 100 g adds about 0.98 N, so 600 g reads about 5.9 N. The graph is a straight line through the origin with gradient about 9.8 N/kg. Values of 9.5 to 10 N/kg are good. A 100 g hanger counts as the first 100 g.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages, draws a line graph with their own scales and finds g from the gradient.

Safety and inclusion

- Clamp the stand to the bench or weigh down its base so it cannot tip. Keep feet clear of hanging masses.
- Add masses gently: a sudden drop can overstretch the spring.
- Learners with limited grip can read the scale while a partner adds masses. The kit works on a low table for seated learners. Hand-held newton balances work if no stand is available.
- Follow your school and local authority guidance on practical work.

Common problems

- **Grams not changed to kilograms:** gives g = 0.0098. Check the mass column is in kg.
- **Balance not zeroed:** every reading is out by the same amount, so the line misses the origin.
- **Reading at an angle:** read the scale at eye level, with the pointer still.

No lab, no time, or a learner absent?

The practical includes a set of sample results, so learners can still complete the averages, graph, value of g, conclusion and evaluation.

Assessment link

This practical gives evidence for planning and carrying out an experiment safely, recording and presenting results, drawing a conclusion and evaluating, and links to the Newton's second law and weight key area of the unit.

Answers: Topic 6

Topic 6: Newton's second law and weight (N4)

1 Force, mass and acceleration

1 F = m a; F = 0.45 × 200; F = 90 N.

2 bike; smaller.

2 Using F = m a

1 $a = \frac{F}{m}$; $a = \frac{150}{75}$; a = 2 m/s².

2 $m = \frac{F}{a}$; $m = \frac{12}{4}$; m = 3 kg.

3 Mass and weight

1 Mass 50 kg everywhere. Weight: Earth 490 N; Moon 80 N; Mars 185 N; Jupiter 1150 N.

2 $m = \frac{W}{g}$; $m = \frac{49}{9.8}$; m = 5 kg.

Practical 6: Mass and weight

Variables: change the mass (kg); measure the weight (N); keep the same: newton balance, zeroed each time, read at eye level, same place (same g).

Prediction, e.g. the bigger the mass, the bigger the weight; doubling the mass doubles the weight, because gravity pulls on each kilogram with the same force.

Equipment: newton balance, 100 g masses (with hanger), clamp stand; top-pan balance useful to check the masses. Stopwatch and thermometer not needed.

Hazards, e.g. clamp stand toppling (clamp the base or weigh it down, keep it away from the edge); spring snapping back if overloaded (stay within the scale).

Headings: Mass (kg), Trial 1, 2, 3 (N), Average (N).

Sample averages: 1.0, 2.0, 2.9, 3.9, 4.9, 5.9 N.

Graph: straight line through the origin, mass (kg) on x, weight (N) on y, even scales.

Conclusion: as the mass increased, the weight increased in proportion (doubling the mass doubles the weight).

Find g: e.g. W = 4.9 N at m = 0.5 kg; $g = \frac{W}{m} = \frac{4.9}{0.5}$ = 9.8 N/kg. Accept 9.5 to 10 N/kg.

Explain: gravity pulls with the same force (about 9.8 N) on every kilogram, so more kilograms means a bigger pull.

Evaluate: (a) e.g. the scale can only be read to 0.1 N, the balance was not zeroed, the masses are not exactly 100 g, parallax when reading. (b) e.g. repeat and average, use a meter with finer divisions, check each mass on a top-pan balance, zero the balance before each reading, use more masses.

Check-up

1 $a = \frac{F}{m}$; $a = \frac{10}{2}$; a = 5 m/s².

2 F = m a; F = 70 × 4; F = 280 N.

3 e.g. mass is the amount of matter, weight is the force of gravity; mass in kg, weight in N; mass stays the same everywhere, weight changes with g.

4 W = m g; W = 80 × 3.7; W = 296 N.

5 g on the Moon is smaller (1.6 N/kg), so her weight is smaller and the same leg force gives her a bigger upward acceleration.

TEACHER NOTES

Practical 7: The best heat shield

Time	One 50-minute lesson: 10 minutes setting up, 10 minutes of cooling, then analysis while waiting.
Kit	Per group: 5 identical polystyrene cups or plastic beakers, thermometer (digital if possible), measuring cylinder, stopwatch, elastic bands, squares of foil, paper towel, bubble wrap, cotton wool, felt or cloth. Kettle for the teacher.
Prep	Cut material squares to the same size. Heat water to about 60 °C (not boiling). Trays to stand cups on.
Expected results	Over 10 minutes an unwrapped cup at 60 °C typically drops 12–16 °C. Materials that trap air (cotton wool, bubble wrap, felt) give the smallest drops. A single layer of shiny foil helps only a little.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages, draws a bar chart with their own scale and evaluates.

Safety and inclusion

- The teacher pours all hot water. Use water at about 60 °C, never boiling, and keep cups on trays so they are not carried.
- Use spirit or digital thermometers, not mercury. Wipe up spills at once.
- Learners who should not be near hot water can do the **ice cube version**: wrap identical ice cubes in each material and time how long each takes to melt (longer means a better insulator). It is slower, so start it at the beginning of the lesson.
- Follow your school and local authority guidance on practical work.

Common problems

- **Uneven wrapping:** different thicknesses spoil the test. One layer each, or the same number of layers.
- **Reading too soon:** stir gently and wait for the reading to settle before recording.
- **Staggered starts:** fill and time cups one after another, or use one timer per cup.

No lab, no time, or a learner absent?

The sample results let learners complete the averages, bar chart, conclusion and evaluation. Rubbing hands or sandpaper on wood is a quick, kit-free model of re-entry heating.

Assessment link

This practical gives evidence for the experiment and investigation outcome of the unit: planning, following a procedure safely, recording and presenting results, drawing a conclusion and evaluating.

Answers: Topic 7

Topic 7: Exploring space (N4)

1 Why explore space?

1 Benefit; risk; benefit; risk.

2 It moves extremely fast (about 28 000 km/h), so it has a lot of kinetic energy and hits very hard.

3 For, e.g. it costs billions that could be spent on hospitals or schools; it is dangerous for astronauts; it creates debris. Against, e.g. satellites give weather forecasts, communication and navigation; spin-offs; jobs; new knowledge.

2 Living in space

1 They are weightless, so they would float off the machine; straps (bungees) pull them down so their muscles and bones work against a force.

2 It makes crumbs, which float about and could get into eyes, lungs or equipment.

3 50 kg. Mass is the amount of matter in her body; it does not depend on gravity.

4 They are above most of the atmosphere, which on Earth absorbs much of the radiation from the Sun and space.

3 Coming home: re-entry

1 Kinetic energy → heat (thermal) energy.

2 So that heat from the hot outside passes through it very slowly and the crew and equipment inside stay cool.

3 Sandpaper stands for the air (atmosphere) rubbing on the craft; the warm wood stands for the spacecraft heating up.

4 It loses kinetic energy too quickly, so it heats up more than the shield can cope with; the crew also feel very large forces.

Practical 7: The best heat shield

Variables: change the wrapping material; measure the temperature drop (°C) in a set time; keep the same: volume of water, starting temperature, time, number or thickness of layers, size and type of cup, lid or no lid, room.

Prediction, e.g. cotton wool or bubble wrap will be the best insulator because they trap air, which is a poor conductor.

Equipment: thermometer, cups, wrapping materials, elastic bands, stopwatch, measuring cylinder. Magnet and newton balance not needed.

Hazards, e.g. glass thermometer breaking (handle carefully, report breakages); spilled water on the floor (wipe up, slip risk).

Headings: Material, Drop 1, 2, 3 (°C), Average drop (°C). (Or start and end temperatures in °C, then drop.)

Sample averages: no wrapping 14 °C; foil 12 °C; paper towel 10 °C; bubble wrap 7 °C; cotton wool 5 °C.

Bar chart: material on the x axis, average temperature drop (°C) on the y axis, even scale, bars of equal width with gaps.

Conclusion: cotton wool was the best insulator, because its water had the smallest temperature drop (5 °C).

Explain: it slows down the movement of heat, so it would keep the inside of a spacecraft cool while the outside is very hot. (Trapped air is a poor conductor.)

Evaluate: (a) the unwrapped cup is a control, to compare against and show how much each material helped. (b) e.g. use a lid on every cup; use a digital thermometer; more repeats; same thickness of each material; start every cup at exactly the same temperature.

Check-up

1 Benefits, e.g. spin-offs, satellites, knowledge, jobs. Risks, e.g. cost, danger to astronauts, space debris, launch failure.

2 An invention made for space that is now used on Earth, e.g. memory foam, phone camera sensor, ear thermometer.

3 e.g. weightlessness weakens muscles and bones: 2 hours of exercise a day; crumbs float: sealed food packs; radiation: shielding and checking doses; limited water: recycling.

4 Friction with the air slows the craft and changes its kinetic energy into heat.

5 It is a very good insulator (a very poor conductor of heat).

TEACHER NOTES

Practical 8: Curved reflectors

Time	One 50-minute lesson. Set up in pairs; each mirror takes about 5 minutes to trace and measure.
Kit	Per pair: ray box with low-voltage power supply, slit comb (3 to 5 slits), a set of concave mirrors or curved plastic mirror strips of different curvature (radius marked), plain A4 paper, ruler, sharp pencil.
Prep	Label each mirror with its radius of curve. Dim the room or use blinds. No ray boxes? Use a bright torch behind a comb, or a foil-lined bowl with a torch beam.
Expected results	Parallel rays cross at a point about half the radius of curvature from the mirror. A deeper curve (smaller radius) brings the focus closer. Repeats should agree to within a few millimetres.
Level	N4 plans the test (variables, prediction, kit, risk, method), repeats readings, averages, draws a line graph with their own scales and evaluates.

Safety and inclusion

- Ray box lamps get hot: handle by the base and allow to cool. Keep power supplies dry.
- Dim rooms: keep bags off the floor and walkways clear. Glass mirrors should be checked for chips; plastic mirrors are safer.
- Learners with limited fine motor control can work with a partner who marks the rays while they position the mirror and read the ruler.
- Follow your school and local authority guidance on practical work.

Common problems

- **Rays not parallel:** move the ray box back or adjust its lens until the rays stay the same distance apart.
- **Fuzzy crossing point:** mark each ray with two crosses, join them with a ruler, and take the centre of the crossing.
- **Measuring from the wrong place:** always measure from the middle of the mirror's surface.

No lab, no time, or a learner absent?

The sample results let learners complete the averages, graph, conclusion and evaluation. The altitude and period table on learning page 2 gives a second data task: learners can plot period against altitude for the ISS, GPS and geostationary satellites and describe the pattern.

Assessment link

This practical gives evidence for the experiment and investigation outcome of the unit: planning, following a procedure safely, recording and presenting results, drawing a conclusion and evaluating.

Answers: Topic 8

Topic 8: Satellites (N4)

1 What is a satellite?

1 A natural satellite formed naturally, e.g. the Moon; an artificial satellite was made and launched by people, e.g. the ISS, a GPS or weather satellite.

2 Walker: GPS. Farmer: weather. Scientist: environment. Ella: communication.

2 Higher orbits take longer

1 The higher the altitude, the longer the period.

2 Between about 1.7 hours and 12 hours (the real value is about 6 hours).

3 The satellite is geostationary: it orbits once every 24 hours as the Earth spins once, so it stays above the same place and the dish always points the same way.

3 Dishes and signal times

1 To reflect the weak signals that hit it so they all meet at the receiver (the focus), giving a stronger signal.

2 $t = \frac{d}{v} = \frac{400\,000}{300\,000\,000} = 0.0013$ s (about 1.3 thousandths of a second).

3 $d = v\,t = 300\,000\,000 \times 0.067 = 20\,100\,000$ m = 20 100 km (about 20 000 km).

Practical 8: Curved reflectors

Variables: change the radius of the curve (cm); measure the distance from mirror to focus (cm); keep the same: rays parallel, same ray box and slits, measured from the centre of the mirror, rays hitting the mirror straight on, same room lighting.

Prediction, e.g. the flatter the mirror (bigger radius), the further away the focus, because the rays are bent back less.

Equipment: ray box, power supply, slit comb, curved mirrors, ruler, plain paper. Thermometer not needed.

Hazards, e.g. working in a dim room (clear bags from the floor); mirror or glass breaking (handle carefully, report breakages); mains power supply (keep water away).

Headings: Radius of curve (cm), Focus 1, 2, 3 (cm), Average (cm).

Sample averages: 5.0 cm, 7.6 cm, 9.9 cm, 12.5 cm, 15.1 cm.

Line graph: radius of curve (cm) on x axis, distance to focus (cm) on y axis; points lie close to a straight line through the origin.

Conclusion: as the radius of the curve increased, the focus moved further from the mirror (the distance is about half the radius).

Explain: all the reflected signals meet only at the focus, so that is where the signal is strongest; anywhere else the receiver would miss most of the signal.

Evaluate: repeats within about 0.6 cm of each other suggest reliable results. Improvement, e.g. use narrower slits for thinner rays; mark rays with crosses and join them with a ruler; darken the room; more repeats; measure to the nearest mm.

Check-up

1 The Moon. Uses, e.g. communication (TV, phone), weather forecasting, environmental monitoring, GPS navigation.

2 longer; 24 hours.

3 It orbits above the equator once every 24 hours, the same time the Earth takes to spin once, so it stays above the same point on the Earth.

4 The curved dish collects signal over a large area and reflects it all to one point, the focus, where the receiver is.

5 $d = 72\,000$ km $= 72\,000\,000$ m; $t = \frac{d}{v} = \frac{72\,000\,000}{300\,000\,000} = 0.24$ s.

TEACHER NOTES

Practical 9: A model solar system

Time	One 50-minute lesson: 15 minutes calculating, 20 minutes outside or in a corridor, 15 minutes graph and analysis.
Kit	Per group: trundle wheel or 30 m measuring tape, 9 cones or markers, planet labels, calculator. Optional: a toilet roll (one sheet is about 11 cm) for a quick indoor version.
Prep	Choose a straight run of at least 50 m (playground edge, field or long corridor). Neptune is 45 m from the Sun at this scale. Check the area is clear of traffic.
Expected results	Scale distances from 0.58 m (Mercury) to 45 m (Neptune). The four inner planets fit within 2.3 m; the gaps grow hugely beyond Mars. Orbit time rises from 0.24 years to 165 years, with a curve that gets steeper.
Level	N4 plans the model (variables, prediction, kit, risk, method), averages repeat pace measurements, calculates scale distances, draws a line graph with their own scales and evaluates.

Safety and inclusion

- Outside: stay away from car parks and roads, check the weather, and walk rather than run. In a corridor, choose a quiet time.
- Learners who cannot pace distances easily can use the trundle wheel or tape, or place the markers and record while a partner measures.
- Follow your school and local authority guidance on work outside the classroom.

Common problems

- **Measuring from the last planet:** every distance must be measured from the Sun marker, not from the planet before.
- **Mixing units:** keep planet distances in millions of km and divide by 100 to get metres.
- **Graph squashed in one corner:** the inner planets crowd together; a good scale still shows them.

No lab, no time, or a learner absent?

The sample data lets learners calculate the scale distances, draw the graph of orbit time against distance, and answer the evaluation without going outside.

Assessment link

This practical gives evidence for the experiment and investigation outcome of the unit: planning, following a procedure safely, recording and presenting results, drawing a conclusion and evaluating.

Answers: Topic 9

Topic 9: Our place in the universe (N4)

1 From planet to universe

1 Galaxy C; exoplanet A; solar system B; moon D.

2 Moon, planet, solar system, galaxy, universe.

3 No. The Moon does not give out its own light; it reflects light from the Sun. A star makes its own light.

2 The light year

1 It is how far light travels in one year, so it is measured in metres (or km).

2 $d = 4.2 \times 9.5 \times 10^{15} = 3.99 \times 10^{16}$ m, about 4.0×10^{16} m (40 000 000 000 000 000 m).

3 $t = \frac{d}{v} = \frac{150\,000\,000\,000}{300\,000\,000} = 500$ s; $\frac{500}{60} =$ 8.3 minutes, about 8 minutes.

4 The light left Andromeda 2.5 million years ago, so we see it as it was then (looking back in time).

3 Exploring the universe

1 e.g. no atmosphere to blur or block the light, so images are sharper; it can detect light (such as some infrared and ultraviolet) that the atmosphere absorbs; no clouds.

2 It would be too hot, so any water would boil away; it could not have liquid water.

3 e.g. liquid water; an atmosphere (to keep it warm and shield it from harmful radiation); oxygen or the right gases.

Practical 9: A model solar system

Variables: compare the planet's distance from the Sun; look at the time for one orbit (Earth years); keep the same: the scale used for every planet; measure every distance from the same Sun marker; same person pacing; same units.

Prediction, e.g. the further from the Sun, the longer the orbit takes, because the planet has further to travel.

Equipment: trundle wheel or measuring tape, cones or markers, planet labels, calculator. Thermometer and stopwatch not needed.

Hazards, e.g. tripping over the tape (keep it flat, walk); cold or wet weather (wear a coat, stay on dry surfaces); in a corridor, other people walking through (work at a quiet time, keep to one side).

Pace: average of 6.2, 6.6 and 6.4 m = 6.4 m for 10 paces, so one pace = 0.64 m.

Headings, e.g. Distance from Sun (million km), Scale distance (m), Number of paces, Time for one orbit (Earth years).

Scale distances: Mercury 0.58 m; Venus 1.08 m; Earth 1.50 m; Mars 2.28 m; Jupiter 7.78 m; Saturn 14.30 m; Uranus 28.70 m; Neptune 45.00 m. Paces (outer planets): Jupiter 12; Saturn 22; Uranus 45; Neptune 70.

Graph: distance from Sun (million km) on the x axis, time for one orbit (Earth years) on the y axis; points rise in a curve that gets steeper.

Conclusion: the further a planet is from the Sun, the longer it takes to orbit once (Mercury 0.24 years, Neptune 165 years).

Explain: it has a longer path to travel, and it moves more slowly because the Sun's gravity is weaker further away.

Evaluate: (a) the planets would be far too small to see or hold (Earth 0.13 mm, the Sun only about 14 mm); (b) a single measurement could be wrong, so repeats and an average make the pace length more reliable; (c) e.g. use a trundle wheel or tape instead of paces; use a larger space and scale; measure each distance twice.

Check-up

1 A planet orbits our Sun; an exoplanet orbits a different star.

2 Earth, solar system, Milky Way, universe.

3 The distance light travels in one year (about 9.5×10^{15} m).

4 $d = 8.6 \times 9.5 \times 10^{15} = 8.17 \times 10^{16}$ m, about 8.2×10^{16} m.

5 e.g. Galileo's telescope showed Jupiter has moons; Hubble showed distant galaxies; probes sent close-ups of other planets; rovers found Mars once had water; telescopes have found exoplanets.

6 It is the right distance from its star for water to be liquid, which life as we know it needs.

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.