REAL-LIFE PHYSICS

Dynamics and Space

Teacher guide

For the National 5 Physics workbook



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Blewis LEARNING

Using the workbooks

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

PRACTICALS

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

PRACTICAL SAFETY

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

NO LAB, NO KIT, OR A LEARNER ABSENT

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

EVIDENCE

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

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TEACHER NOTES

Practical 1: Does the card length change the speed you measure?

Time	One 50-minute lesson in pairs. Five card lengths with three runs each takes about 25 minutes.
Kit per group	Dynamics trolley, ramp (about 1.5 m) on books or a block, one light gate with timer or data logger, cards of 2 to 6 cm (cut from thin card), ruler, tape, a stop at the bottom.
Prep	Check light gates read in seconds to 4 decimal places and that the card height passes through the beam. A low ramp angle keeps the times readable.
Expected results	Speeds of roughly 0.8 m/s, rising by a few percent with card length because the trolley accelerates while the card passes. Short cards give the best estimate of instantaneous speed.
Level	N5 plans the test, repeats, finds the mean and random uncertainty, draws a graph with a line of best fit and evaluates.

Safety and inclusion

- Stop the trolley at the bottom; keep feet and leads clear of the ramp.
- All roles can be done seated; a learner can run the logger or record while others release.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Card in cm:** convert to metres before dividing.
- **Pushing the trolley:** release from rest at a marked point every time.
- **Card not square to the beam:** it gives a longer time and a lower speed.

No lab, no time, or a learner absent?

The sample results let learners complete the means, speeds, graph, conclusion and evaluation without the practical.

Assessment link

Evidence of planning, recording, mean and uncertainty, graphing and evaluating. Good practice for the assignment: compare with a value from another source and reference it.

Answers: Topic 1

Topic 1: Vectors and scalars (N5)

1 Scalars and vectors

1 distance S; force V; mass S; velocity V; energy S; acceleration V.

2 Distance 1200 m; displacement 0 m. Average speed = $\frac{1200}{400}$ = 3.0 m/s. Average velocity = 0 m/s (no displacement).

3 Weight is a force, which acts in a direction (downwards, towards the centre of the planet). Mass is the amount of matter, which has no direction.

2 Adding vectors

1 F = √(80² + 60²) = 100 N; tan θ = $\frac{60}{80}$, θ = 37° north of east; bearing 053.

2 v = √(3.0² + 1.0²) = 3.2 m/s; tan θ = $\frac{1.0}{3.0}$, θ = 18° east of north; bearing 018.

3 900 − 350 = 550 N forward.

3 Average and instantaneous speed

1 d = 18 000 m, t = 50 × 60 = 3000 s; $\bar{v} = \frac{d}{t} = \frac{18\,000}{3000}$ = 6.0 m/s.

2 v = $\frac{0.050}{0.040}$ = 1.25 m/s, so 1.3 m/s.

3 The speed changes while the card passes; a short card is timed over a very short time, so the measured (average) speed is very close to the speed at that instant.

Practical 1: Does the card length change the speed you measure?

Variables: change the card length; measure the time to pass through the light gate, then calculate speed; keep the same: release point, ramp angle, light-gate position, trolley.

Prediction, e.g. longer cards give a slightly higher measured speed, because the trolley is speeding up while the card passes.

Equipment: trolley, ramp, light gate, timer or logger, cards, ruler. Not needed: thermometer, balance.

Hazards, e.g. ramp slipping (clamp or wedge it); trailing light-gate leads (tidy them along the bench).

Method key points: mark a release point; measure each card with a ruler; release (do not push) from the mark; light gate at a fixed distance; three runs per card; mean time; speed = card length (in m) ÷ mean time; uncertainty = $\frac{\text{range}}{3.}$

Sample results: 2.0 cm: 0.0250 s, 0.80 m/s; 3.0 cm: 0.0370 s, 0.81 m/s; 4.0 cm: 0.0488 s, 0.82 m/s; 5.0 cm: 0.0602 s, 0.83 m/s; 6.0 cm: 0.0714 s, 0.84 m/s. The speeds rise slightly with card length.

Uncertainty for the 4.0 cm card: $\frac{0.0490 - 0.0486}{3}$ = ±0.0001 s, so the mean time is 0.0488 ± 0.0001 s.

Graph: card length (cm) on x, speed (m/s) on y, a straight line of best fit rising gently.

Conclusion: as the card length increased, the measured speed increased slightly, because the trolley speeds up while a long card passes the gate.

Evaluate: (a) the shortest card (2.0 cm), because the trolley's speed changes least while it is timed. (b) Reliability: more repeats and take the mean. Accuracy: measure the card length with a vernier or more carefully, make sure the card passes square through the beam.

Check-up

1 (a) 300 + 400 = 700 m (1). (b) s = √(300² + 400²) (1) = 500 m (1); tan θ = $\frac{300}{400}$, θ = 37° west of south, bearing 217 (1).

2 $\bar{v} = \frac{s}{t}$ (1); $\bar{v} = \frac{500}{50}$ (1); $\bar{v}$ = 10 m/s at bearing 217 (1).

3 v = √(5.0² + 2.0²) = 5.4 m/s (1, 1); tan θ = $\frac{2.0}{5.0}$, θ = 22° south of east, bearing 112 (1).

4 v = $\frac{d}{t}$ (1); v = $\frac{0.025}{0.020}$ (1); v = 1.25 m/s, so 1.3 m/s (1).

TEACHER NOTES

Practical 2: Velocity–time graphs with a data logger

Time	One 50-minute lesson in pairs. Five heights with three runs takes about 25 minutes once the logger is set up.
Kit per group	Trolley, ramp about 1.5 m long, blocks or books, motion (ultrasound) sensor and data logger or interface with software, metre stick, a stop at the bottom.
Prep	Set the logger to record velocity at 20 to 50 readings per second. Mount the sensor at the top of the ramp pointing down it, at least 20 cm behind the trolley's start.
Expected results	Velocity after 1.0 s rises roughly in proportion to ramp height (about 0.55 to 1.7 m/s from 10 cm to 30 cm on a 1.5 m ramp; friction keeps them a little below the frictionless values). The logger v–t graph is a straight line through the origin.
Level	N5 plans, repeats, finds mean and random uncertainty, draws a graph and uses the area under a v–t graph.

Safety and inclusion

- Stop the trolley at the bottom; keep the ramp clamped. Keep leads tidy.
- Learners can share roles (release, logger, record); all can be done seated.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Sensor sees a hand or the bench:** angle it slightly and keep hands out of the beam.
- **Graph not starting at zero:** start logging before releasing and line up t = 0 with the release.
- **Area units:** m/s × s = m; check the axes.

No lab, no time, or a learner absent?

The sample results and logger readings let learners complete the means, uncertainties, graphs and area calculation without the practical.

Assessment link

Evidence of planning, data handling, uncertainty, graphing and using the area under a v–t graph.

Answers: Topic 2

Topic 2: Velocity–time graphs (N5)

1 Reading velocity–time graphs

1 P to Q: uniform acceleration from 0 to 15 m/s in 10 s. Q to R: constant velocity of 15 m/s for 30 s. R to S: uniform deceleration from 15 m/s to rest in 10 s.

2 They have the same size of acceleration (1.5 m/s²): the lines are equally steep. P to Q is speeding up; R to S is slowing down.

3 A straight line starting at a positive velocity, sloping down through zero (the top of the throw) to an equal negative velocity.

2 Displacement from the area

1 ½ × 4 × 8 + 8 × 8 + ½ × 4 × 8 = 96 m.

2 $\bar{v} = \frac{s}{t} = \frac{96}{16}$ = 6.0 m/s.

3 Distance adds the path up and back; displacement is measured from start to finish, so the parts up and down cancel.

3 Drawing v–t graphs from data

1 Straight line from (0, 0) to (4, 4.8), horizontal to (6, 4.8), straight line down to (8, 0); axes labelled with units.

2 a = $\frac{4.8 - 0}{4}$ = 1.2 m/s². Displacement = ½ × 4 × 4.8 + 2 × 4.8 + ½ × 2 × 4.8 = 24.0 m.

3 Speed has no direction, so it cannot be negative. The speed is zero at each end of the swing, where it changes direction.

Practical 2: Velocity–time graphs with a data logger

Variables: change the ramp height; measure the velocity 1.0 s after release (from the logger); keep the same: trolley, ramp length and surface, release point, sensor position.

Prediction, e.g. a higher ramp gives a greater velocity because the trolley accelerates more.

Equipment: trolley, ramp, motion sensor, data logger, metre stick. Not needed: stopwatch, thermometer.

Hazards, e.g. trolley running off the end (stop at the bottom); trailing leads (tape them down).

Sample results (mean ± uncertainty): 10 cm: 0.55 ± 0.01 m/s; 15 cm: 0.83 ± 0.01 m/s; 20 cm: 1.12 ± 0.01 m/s; 25 cm: 1.38 ± 0.01 m/s; 30 cm: 1.67 ± 0.03 m/s.

Graph: ramp height on x, mean velocity on y; straight line of best fit through (or close to) the origin.

8a Area = ½ × 1.0 × 1.12 = 0.56 m.

Conclusion: as the ramp height increased, the velocity after 1.0 s increased (roughly in proportion).

Evaluate: (a) 30 cm (range 0.09 m/s, uncertainty ±0.03 m/s); small differences in release or the sensor picking up the hand. (b) e.g. more repeats (reliability); release with a gate or ruler so it is not pushed (accuracy); clamp the sensor so it does not move.

Check-up

1 Accelerates uniformly from rest to 10 m/s in 5 s (1); constant velocity of 10 m/s for 10 s (1); decelerates uniformly to rest in 5 s (1).

2 Area: ½ × 5 × 10 + 10 × 10 + ½ × 5 × 10 (1, 1) = 150 m (1).

3 $\bar{v} = \frac{s}{t}$ (1); $\bar{v} = \frac{150}{20}$ (1); $\bar{v}$ = 7.5 m/s (1).

4 The velocity–time graph crosses the time axis and goes negative (1); the speed–time graph stays above the axis, making a V shape (1).

TEACHER NOTES

Practical 3: How does the slope affect acceleration?

Time	One 50-minute lesson in pairs. Five heights with three runs takes about 25 minutes.
Kit per group	Trolley, ramp about 1.2 m, blocks, one light gate with an interface that calculates acceleration from a double-mask card (or two gates and a single card), metre stick, a soft stop.
Prep	Make double-mask cards with two 2.0 cm tabs and a 2.0 cm gap. Check the logger's acceleration setting and that the tabs pass through the beam.
Expected results	Acceleration rises roughly in proportion to height: about 0.33 m/s² at 5 cm to 1.6 m/s² at 25 cm on a 1.2 m ramp. Friction gives a small intercept.
Level	N5 plans, repeats, mean and random uncertainty, graph with line of best fit, prediction from the graph, evaluation.

Safety and inclusion

- Catch the trolley with a soft stop at the bottom; clamp the ramp.
- Learners can share roles; all can be done seated.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Units:** card lengths in metres before dividing by time.
- **Release:** release from rest at the same mark, never pushed.
- **Negative signs:** stress that a deceleration is a negative acceleration in $a = \frac{v - u}{t}$.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, graph, prediction and evaluation without the practical.

Assessment link

Evidence of planning, mean and uncertainty, graphing and evaluation; links directly to the named N5 experiment to measure acceleration.

Answers: Topic 3

Topic 3: Acceleration (N5)

1 Calculating acceleration

1 $v = u + a\,t = 3.0 + 0.50 \times 8.0 = 7.0$ m/s

2 $t = \dfrac{v - u}{a} = \dfrac{0 - 4.8}{-1.2} = 4.0$ s

2 Acceleration from a graph

1 $a = \dfrac{0 - 18}{20 - 14} = -3.0$ m/s² (a deceleration of 3.0 m/s²)

2 0 m/s². The line is horizontal: the velocity does not change.

3 Rectangle 8 × 2 = 16 m; triangle ½ × 8 × 16 = 64 m; total 80 m.

3 Measuring acceleration

1 $u = \dfrac{0.050}{0.10} = 0.50$ m/s; $v = \dfrac{0.050}{0.050} = 1.0$ m/s; $a = \dfrac{1.0 - 0.50}{0.40} = 1.25$ m/s², so 1.3 m/s².

2 The time for the card at gate 1, the time for the card at gate 2, and the time between the gates.

Practical 3: How does the slope affect acceleration?

Variables: change the ramp height; measure the acceleration; keep the same: trolley and its mass, ramp length and surface, release point, card.

Prediction, e.g. a higher ramp gives a greater acceleration because more of the trolley's weight acts down the slope.

Equipment: trolley, ramp, light gate, logger, double-mask card, metre stick. Not needed: balance.

Hazards, e.g. ramp collapsing (clamp it); trailing leads (tidy them).

Sample results (mean ± uncertainty): 5 cm: 0.33 ± 0.01 m/s²; 10 cm: 0.65 ± 0.01 m/s²; 15 cm: 0.98 ± 0.01 m/s²; 20 cm: 1.31 ± 0.01 m/s²; 25 cm: 1.63 ± 0.01 m/s².

Graph: ramp height on x, mean acceleration on y; a straight line of best fit close to the origin.

Conclusion: as the ramp height increased, the acceleration increased in proportion.

Use your graph: about 0.78 m/s² (accept 0.75 to 0.80).

Evaluate: (a) friction on the ramp means a small height is needed before the trolley moves at all; heights measured from the bench may be slightly off. (b) e.g. more repeats (reliability); measure the height at both ends of the ramp, or use shorter, narrower tabs so the speed changes less while each tab is timed (accuracy).

Check-up

1 $a = \dfrac{v - u}{t}$ (1); $a = \dfrac{14 - 2.0}{8.0}$ (1); $a = 1.5$ m/s² (1).

2 $v = u + a\,t$ (1); $v = 0 + 4.0 \times 2.5$ (1); $v = 10$ m/s (1).

3 $t = \dfrac{v - u}{a}$ (1); $t = \dfrac{0 - 30}{-6.0}$ (1); $t = 5.0$ s (1).

4 $u = \dfrac{0.020}{0.040} = 0.50$ m/s and $v = \dfrac{0.020}{0.025} = 0.80$ m/s (1); $a = \dfrac{v - u}{t}$ (1); $a = \dfrac{0.80 - 0.50}{0.30}$ (1); $a = 1.0$ m/s² (1).

TEACHER NOTES

Practical 4: Force and acceleration

Time	One 50-minute lesson in pairs. Five forces with three runs takes about 25 minutes after friction compensation.
Kit per group	Trolley (about 0.5 kg), runway, pulley clamp, string, mass hanger with five 10 g masses, one light gate and logger with a double-mask card (or two gates), padded box under the hanger, stop block.
Prep	Tilt the runway so a gently pushed trolley rolls at steady speed (friction compensated). Keep the five masses on the trolley and move them to the hanger one at a time so the total mass stays the same.
Expected results	About 0.18 m/s² per 0.10 N with a total mass of 0.55 kg; a straight line through the origin. Mass from the gradient close to 0.55 kg.
Level	N5 plans, repeats, finds mean and uncertainty, graphs, and uses F = m a to analyse.

Safety and inclusion

- Padding under falling masses; stop block before the pulley; keep feet clear.
- Learners can share roles; all can be done seated.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Changing the total mass:** adding new masses to the hanger changes both F and m. Move masses from trolley to hanger.
- **Force in grams:** force = mass in kg × 9.8 N/kg.
- **Ramp not compensated:** the line will not pass through the origin.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, graph, mass check and evaluation without the practical.

Assessment link

Evidence of planning, data handling, uncertainty, graphing and analysis using F = m a.

Answers: Topic 4

Topic 4: Newton's laws (N5)

1 Balanced forces

1 1800 N. The car moves at constant velocity, so the forces are balanced (Newton's first law).

2 0 N (the forces on it are balanced).

3 Reduced, e.g. oil on the chain, streamlined riding position. Increased, e.g. brake pads gripping the rim, tyre tread.

2 Unbalanced forces and weight

1 F = 350 − 140 = 210 N; $a = \frac{F}{m} = \frac{210}{70} = 3.0$ m/s².

2 W = m g = 180 × 3.7 = 666 N, so 670 N.

3 Newton pairs and terminal velocity

1 The oars push the water backwards; the water pushes the oars (and boat) forwards with an equal and opposite force.

2 At first weight is greater than air resistance, so she accelerates. Air resistance increases with speed until it equals her weight. The forces are then balanced, so her velocity is constant.

3 At terminal velocity air resistance = weight = 75 × 9.8 = 735 N, so 740 N.

Practical 4: Force and acceleration

Variables: change the unbalanced force (weight of hanging masses); measure the acceleration; keep the same: total moving mass, runway slope (friction-compensated), card, release point.

Prediction, e.g. acceleration increases in proportion to the force, because F = m a.

Equipment: trolley, runway, 10 g masses on a hanger with string and pulley, light gate, double-mask card. Not needed: thermometer; balance only to check the total mass.

Hazards, e.g. falling masses (padding underneath); trolley hitting the pulley (stop block).

Sample results (mean ± uncertainty): 0.10 N: 0.18 ± 0.01 m/s²; 0.20 N: 0.36 ± 0.01 m/s²; 0.29 N: 0.53 ± 0.01 m/s²; 0.39 N: 0.71 ± 0.01 m/s²; 0.49 N: 0.89 ± 0.01 m/s².

Graph: force on x, mean acceleration on y; a straight line through the origin.

Conclusion: as the unbalanced force increased, the acceleration increased in direct proportion.

9a e.g. $m = \frac{F}{a} = \frac{0.49}{0.89} = 0.55$ kg, close to 0.55 kg.

Evaluate: (a) acceleration also depends on mass; only the force should change. (b) e.g. more repeats (reliability); check friction compensation carefully, use a shorter, narrower card tab so the speed changes less while it is timed (accuracy).

Check-up

1 4000 N (1); the velocity is constant, so the forces are balanced (1).

2 F = 2700 − 450 = 2250 N (1); F = m a (1); 2250 = 900 × a (1); a = 2.5 m/s² (1).

3 W = m g (1); W = 85 × 1.6 (1); W = 136 N, so 140 N (1).

4 Air resistance increases and is now greater than her weight (1), so she decelerates (1); as she slows, air resistance falls until it equals her weight, giving a new lower terminal velocity (1).

TEACHER NOTES

Practical 5: From potential to kinetic energy

Time	One 50-minute lesson in groups of three. Five heights with three runs each takes about 25 minutes.
Kit per group	Dynamics trolley (or a toy car with low-friction wheels), ramp or board, blocks, light gate and timer or data logger, 5.0 cm card, metre stick, balance, end stop.
Prep	Set the light gate so the card passes straight through the beam near the bottom of the slope. Check the timer reads to at least 0.0001 s, or set the logger to calculate speed from the card length.
Expected results	Speed rises from about 0.9 m/s at h = 0.05 m to about 2.1 m/s at 0.25 m. E_k gained is usually 80 to 90% of E_p lost; the gap grows with friction.
Level	N5 plans the test, repeats, finds the mean and random uncertainty, draws a curve of best fit, compares E_p and E_k and evaluates.

Safety and inclusion

- Use an end stop; keep feet away from the end of the ramp. Clamp or support ramps so they cannot slide.
- Release the trolley by letting go, not pushing. All roles can be done seated.
- Risk assess for your own room and learners, following your employer's policy and SSERC guidance.

Common problems

- **Height measured along the slope:** h is the vertical height.
- **Card at an angle:** the beam is broken for longer, so the speed is too low.
- **Mass in grams:** convert to kilograms before calculating energy.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, speeds, graph and energy check.

Assessment link

Develops the assignment skills: planning, raw data in a table with units, mean and uncertainty, a graph with a line of best fit, comparing with a reliable source, and evaluation. Also gives practice in $E_p = m\ g\ h$ and $E_k = ½\ m\ v^2$.

Answers: Topic 5

Topic 5: Energy (N5)

1 Energy stores and work done

1 $E_w = F\ d = 65 \times 12 = 780$ J

2 $E_p = m\ g\ h = 48 \times 9.8 \times 9.0 = 4234$ J (4200 J)

2 Kinetic energy

1 $E_k = ½\ m\ v^2 = 0.5 \times 0.16 \times 25^2 = 50$ J

2 $4000 = 0.5 \times 80 \times v^2$, $v^2 = 100$, $v = 10$ m/s

3 No. E_k depends on v^2, so doubling the speed gives four times the kinetic energy (100 m^2/s^2 becomes 400).

3 Conservation of energy problems

1 E_p lost = E_k gained; $m\ g\ h = ½\ m\ v^2$; $v = \sqrt{(2 \times 9.8 \times 3.2)} = 7.9$ m/s

2 (a) $E_p = 50 \times 9.8 \times 8.0 = 3920$ J; $E_k = 0.5 \times 50 \times 10^2 = 2500$ J. (b) 3920 − 2500 = 1420 J transferred as heat and sound (friction and air resistance).

Practical 5: From potential to kinetic energy

Variables: change the release height (m); measure the time for the card to pass through the light gate, then the speed (m/s); keep the same: trolley and mass, card length, ramp angle and surface, light gate position, releasing from rest.

Prediction, e.g. the higher the release point, the faster the trolley, because it has more E_p to change into E_k.

Equipment: trolley, ramp, light gate and timer, card, metre stick, balance. Not needed: thermometer.

Hazards, e.g. ramp collapsing or slipping (clamp it, support it on a stable bench); trolley hitting fingers (release by letting go, do not push).

Method key points: measure h vertically from the bench to the same point on the trolley each time; release from rest without pushing; light gate near the bottom; measure the card length; 3 repeats per height; mean time; v = card length ÷ mean time; uncertainty = (max − min) ÷ number of readings.

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

Sample results: h = 0.050 m: mean 0.0539 s, v = 0.93 m/s; h = 0.100 m: mean 0.0383 s, v = 1.30 m/s; h = 0.150 m: mean 0.0312 s, v = 1.60 m/s; h = 0.200 m: mean 0.0271 s, v = 1.85 m/s; h = 0.250 m: mean 0.0243 s, v = 2.05 m/s;

Graph: a smooth curve rising less steeply as h increases (v is proportional to √h).

Conclusion: as the release height increased, the speed at the bottom increased (but not in direct proportion).

Energy check: (a) $E_p = 0.80 \times 9.8 \times 0.200 = 1.57$ J; v = 1.85 m/s, $E_k = 0.5 \times 0.80 \times 1.85^2 = 1.36$ J.

(b) Some energy is transferred as heat and sound because of friction at the wheels and air resistance.

Evaluate: e.g. measure the card length with vernier calipers or a ruler to the nearest mm; make sure the card passes straight through the beam; more repeats reduce the effect of random errors.

Assignment link: g ≈ 9.8 N/kg; the value from $v^2 = 2\ g\ h$ will be smaller because energy is lost to friction.

Check-up

1 Energy cannot be created or destroyed; it can only be changed from one form (store) to another (1).

2 $E_p = m\ g\ h$ (1) = 350 × 9.8 × 14 (1) = 48020 J, 48 000 J (1)

3 $E_k = ½\ m\ v^2$ (1); $47 = 0.5 \times 0.058 \times v^2$ (1); v = 40 m/s (1)

4 (a) $E_p = 25 \times 9.8 \times 2.5 = 613$ J (1); $E_k = 0.5 \times 25 \times 4.0^2 = 200$ J (1); energy lost = 613 − 200 (1) = 413 J (1). (b) e.g. make the surface smoother or polish it / use a low-friction coating, to reduce friction (1).

TEACHER NOTES

Practical 6: Where will the ball land?

Time	One 50-minute lesson in groups of three. Five speeds with three landings each takes about 25 minutes.
Kit per group	Curved or straight ramp clamped at the edge of a bench, steel ball or marble, light gate and timer (speed mode), sand tray or carbon paper on white paper, metre stick, plumb line.
Prep	Mark five release points on the ramp. Set the light gate right at the bench edge so it measures the launch speed. Bench height about 0.90 m.
Expected results	Range is directly proportional to speed; the gradient is close to the time of flight, about 0.43 s for a 0.90 m drop. Measured ranges are usually a little short because the ball is still slightly slowing as it leaves.
Level	N5 plans the test, repeats, finds the mean and uncertainty, draws a line of best fit, compares the gradient with theory and evaluates.

Safety and inclusion

- Clamp the ramp. Keep the landing area clear and collect balls immediately so nobody slips.
- All roles can be done seated: release, read the timer, mark the landing point, record.
- Risk assess for your own room and learners, following your employer's policy and SSERC guidance.

Common problems

- **Range measured from the bench leg:** measure from directly below the edge (plumb line).
- **Light gate too far up the ramp:** it measures a speed lower than the launch speed.
- **Using vertical speed in s = v t:** only the horizontal velocity gives the range.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, graph, gradient and comparison with theory.

Assessment link

Develops the assignment skills: raw data with units, mean and uncertainty, a straight-line graph, a gradient compared with a theoretical or published value, and evaluation. Also gives practice in horizontal-launch calculations.

Answers: Topic 6

Topic 6: Projectile motion (N5)

1 Two motions at once

1 They land at the same time. Both start with zero vertical velocity and have the same vertical acceleration (9.8 m/s²); the horizontal motion does not affect the vertical motion.

2 Horizontal velocity stays the same; vertical velocity increases.

2 Projectile calculations

1 $s = v\,t = 3.5 \times 0.60 = 2.1$ m

2 $v = u + a\,t = 0 + 9.8 \times 0.60 = 5.9$ m/s (downwards)

3 Height = ½ × 0.60 × 5.88 = 1.8 m

3 Satellites as projectiles

1 Its weight (the gravitational force of the Earth), acting towards the centre of the Earth.

2 It moves sideways so fast that, as it falls, the Earth's surface curves away beneath it at the same rate, so it keeps falling round the Earth.

3 (a) The same time of flight (same height, zero vertical velocity at the start). (b) The rocket travels twice as far.

Practical 6: Where will the ball land?

Variables: change the horizontal speed (change the release point on the ramp); measure the range (m); keep the same: the bench height, the ball, the ramp, where the range is measured from.

Prediction, e.g. the range is directly proportional to the speed, because the time of flight is the same each time.

Equipment: ramp, light gate and timer, metre stick or tape measure, sand tray. Not needed: balance, thermometer.

Hazards, e.g. ramp falling off the bench (clamp it); people walking into the landing area (mark it off, stand to the side).

Method key points: release from marked points on the ramp; the light gate at the bench edge gives the horizontal speed; mark the landing point in sand (or carbon paper); measure from directly below the bench edge (use a plumb line); 3 repeats; mean; uncertainty = (max − min) ÷ number of readings.

Sample results: 0.80 m/s: mean 0.33 m ± 0.01 m; 1.10 m/s: mean 0.46 m ± 0.01 m; 1.40 m/s: mean 0.59 m ± 0.01 m; 1.70 m/s: mean 0.71 m ± 0.01 m; 2.00 m/s: mean 0.84 m ± 0.01 m;

Graph: a straight line through the origin, so range is directly proportional to horizontal speed.

Compare with theory: (a) $s = v\,t = 1.40 \times 0.43 = 0.60$ m (measured 0.59 m). (b) Gradient ≈ 0.42 s, the time of flight (theory 0.43 s).

Evaluate: e.g. use carbon paper on the landing spot; use a plumb line to find the point directly below the edge; take more repeats.

Check-up

1 (a) $s = v\,t$ (1) = 60 × 9.0 (1) = 540 m (1). (b) $v = u + a\,t$ (1); $v = 0 + 9.8 \times 9.0$ (1) = 88 m/s (1). (c) area under v–t graph = ½ × 9.0 × 88.2 (2) = 397 m, 400 m (1). (d) 60 m/s (1); there is no horizontal force (air resistance ignored), so the horizontal velocity is constant (1).

2 The satellite is falling towards the Earth because of its weight (1), but it moves sideways fast enough that the Earth's surface curves away at the same rate, so it falls round the Earth (1).

TEACHER NOTES

Practical 7: Testing a model heat shield

Time	One 50-minute lesson in groups of three. Each run takes 5 minutes; groups can share the work so each does one layer count three times and results are pooled.
Kit per group	250 cm³ beaker on a tray, temperature sensor and logger (or thermometer), stopwatch, 10 cm squares of corrugated card (3 mm), access to a kettle and thermometer for the teacher.
Prep	The teacher mixes water to 60 °C in a jug and fills each beaker to the same mark. Learners never pour or carry the hot water. Have spare card so each run uses dry layers.
Expected results	About a 10 °C rise above one layer after 5 minutes, falling to about 3 °C above five layers. The curve levels off: each extra layer helps less.
Level	N5 plans the test, repeats, finds the mean and uncertainty, draws a curve of best fit and evaluates, linking the result to re-entry and launch mass.

Safety and inclusion

- Hot water at 60 °C can scald: teacher fills, beakers stay on trays, learners do not lift them. Tape sensor leads down.
- All roles can be done seated. A learner who prefers not to be near hot water can time and record.
- Risk assess for your own room and learners, following your employer's policy and SSERC guidance.

Common problems

- **Water cooling between runs:** use fresh 60 °C water for every run.
- **Sensor not touching the card:** rest it in the same place on top each time.
- **Wet card:** condensation makes damp card conduct heat better; use dry squares each time.

No lab, no time, or a learner absent?

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

Assessment link

Develops the assignment skills: planning, raw data in a table with units, mean and uncertainty, a curve of best fit, comparing with researched information on real heat shields, and evaluation.

Answers: Topic 7

Topic 7: Space exploration (N5)

1 Satellites and their orbits

1 Any two, e.g. navigation (GPS), weather forecasting, communications (phones, internet), observing the Earth.

2 Satellite 3 (higher orbit, longer period).

3 Its period is 24 hours, the same as the Earth's rotation, so it stays above the same point on the equator.

4 Lower: its period is shorter than 24 hours, and lower orbits have shorter periods.

2 Launch, landing and weight

1 $W = m\,g = 900 \times 3.7 = 3330$ N

2 Weight on the Moon = $1500 \times 1.6 = 2400$ N; unbalanced force = $3600 - 2400 = 1200$ N upwards (so the lander slows down).

3 Challenges, risks and benefits

1 It has a huge amount of kinetic energy; friction with the atmosphere changes this into heat, which would destroy the craft without a heat shield.

2 There is no friction or air resistance in space, so there is no unbalanced force and it continues at constant velocity (Newton's first law).

3 Risk, e.g. radiation exposure, failure of life support, re-entry heating, the large fuel load. Benefit, e.g. satellite forecasting and navigation, new materials, medical technology.

Practical 7: Testing a model heat shield

Variables: change the number of layers of card; measure the temperature rise above the card after 5 minutes (°C); keep the same: starting water temperature and volume, the material, the time, the sensor position.

Prediction, e.g. more layers give a smaller temperature rise, because more insulation slows the heat getting through.

Equipment: beaker, temperature sensor (or thermometer), stopwatch, card squares (the teacher heats the water). Not needed: light gate, ruler.

Hazards, e.g. glass beaker breaking (use a tray, plastic beaker if possible); sensor lead pulling the beaker over (tape the lead down).

Method key points: teacher fills the beaker to the same mark with water at 60 °C each time; place the layers and sensor; record the start temperature; record after exactly 5 minutes; 3 repeats; mean; uncertainty.

Sample results: 1 layer: 9.8 ± 0.2 °C; 2 layers: 6.6 ± 0.1 °C; 3 layers: 4.9 ± 0.1 °C; 4 layers: 3.9 ± 0.1 °C; 5 layers: 3.2 ± 0.1 °C;

Graph: a curve falling steeply at first, then levelling off.

Conclusion: as the number of layers increased, the temperature rise decreased, but each extra layer made less difference.

Apply it: a lighter shield means a smaller total mass, so for the same thrust the unbalanced force gives a bigger acceleration (or less fuel is needed).

Evaluate: (a) use fresh water at a measured starting temperature each time (or a water bath). (b) More repeats and calculate the mean; keep the room conditions the same.

Check-up

1 24 hours (1); about 36 000 km (1).

2 (a) $W = m\,g$ (1) $= 8.0 \times 10^5 \times 9.8$ (1) $= 7.8 \times 10^6$ N (7.84×10^6 N) (1). (b) unbalanced force $= 1.2 \times 10^7 - 7.84 \times 10^6 = 4.16 \times 10^6$ N (1); $a = \frac{F}{m}$ (1); $a = 4.16 \times 10^6 \div (8.0 \times 10^5)$ (1) $= 5.2$ m/s² (1). (c) Fuel is used, so the mass decreases (and the weight decreases), so the acceleration increases (1).

3 $g = \frac{W}{m}$ (1) $= \frac{4620}{420}$ (1) $= 11$ N/kg, so the planet is Neptune (11 N/kg) (1).

TEACHER NOTES

Practical 8: How does brightness depend on distance?

Time	One 50-minute lesson in pairs or threes. Five distances with three readings each takes about 20 minutes.
Kit per group	Small 12 V lamp in a holder with power supply, light meter or phone with a free light-meter app, metre stick, card tube or black card to shield the meter from stray light.
Prep	Darken the room as far as is safe; keep one dim light on. Check that phone sensors are on the front (near the camera). Mark the filament position on the bench.
Expected results	Intensity falls to about a quarter when the distance doubles (inverse square). $I \times d^2$ is roughly constant (about 50 lux m^2). Phone sensors vary, so compare patterns rather than values.
Spectra demonstration	If you have discharge lamps and hand spectroscopes, a teacher demonstration of line spectra (hydrogen, helium, sodium) links well to learn page 3. Discharge lamps run at high voltage and get hot: teacher only, following your local rules.
Level	N5 plans the test, repeats, finds the mean and uncertainty, draws a curve of best fit and spots the inverse square pattern.

Safety and inclusion

- Lamps get hot; let them cool. In a darkened room keep floors clear and leads taped down.
- All roles can be done seated. Learners who are uncomfortable in the dark can record by a dim light.
- Risk assess for your own room and learners, following your employer's policy and SSERC guidance.

Common problems

- **Background light:** record it and subtract it, or darken the room more.
- **Sensor angle:** tilting the phone changes the reading a lot; keep it square to the lamp.

No lab, no time, or a learner absent?

The sample results let learners complete the means, uncertainties, graph and pattern questions.

Assessment link

Develops the assignment skills: raw data with units, mean and uncertainty, a curve of best fit, comparing with a published law, and evaluation.

Answers: Topic 8

Topic 8: Cosmology (N5)

1 Distances in space

1 $d = 2.5 \times 10^6 \times 9.5 \times 10^{15} = 2.4 \times 10^{22}$ m

2 $5.7 \times 10^{17} \div 9.5 \times 10^{15} = 60$ light-years

2 The Big Bang and how we know

1 About 14 billion years.

2 e.g. light from distant galaxies is red-shifted (stretched to longer wavelengths), showing they are moving away from us; more distant galaxies move away faster; the microwave background glow comes from every direction.

3 X-rays are absorbed by the Earth's atmosphere, so they do not reach the ground.

3 What stars are made of

1 Hydrogen and sodium: all the lines of each of these elements appear in the star's spectrum.

2 Helium (or calcium): its lines are not all in the star's spectrum.

3 A continuous spectrum has all colours with no gaps; a line spectrum has only certain bright lines (wavelengths).

Practical 8: How does brightness depend on distance?

Variables: change the distance from the lamp (m); measure the light intensity (lux); keep the same: the lamp and supply voltage, the light meter and its angle, the room darkness.

Prediction, e.g. the further away, the lower the intensity, because the light spreads out over a bigger area.

Equipment: lamp, power supply, light meter (phone app), metre stick. Not needed: prism, thermometer.

Hazards, e.g. working in a darkened room (clear bags and stools away, keep a dim light on); trailing leads (tape them down).

Method key points: darken the room and record the background reading; measure d from the filament to the sensor; point the sensor straight at the lamp; take 3 readings at each distance; mean; uncertainty.

Sample results: 0.20 m: 1250 ± 7 lux ($I \times d^2 = 50$); 0.30 m: 556 ± 4 lux ($I \times d^2 = 50$); 0.40 m: 313 ± 3 lux ($I \times d^2 = 50$); 0.50 m: 200 ± 2 lux ($I \times d^2 = 50$); 0.60 m: 139 ± 1 lux ($I \times d^2 = 50$);

Graph: a curve falling steeply then levelling off.

Conclusion: as the distance increased, the light intensity decreased (more and more slowly).

Pattern: (a) when the distance doubles, the intensity falls to about one quarter (1250 to 313 lux). (b) The dimmer star is further away.

Evaluate: e.g. light from windows or other lamps (darken the room, subtract background); not measuring from the filament (use a fixed mark).

Check-up

1 d = number of light-years $\times 9.5 \times 10^{15}$ m (or d = v t) (1); $d = 8.7 \times 9.5 \times 10^{15}$ (1); $d = 8.3 \times 10^{16}$ m (1).

2 The universe began about 14 billion years ago from a tiny, hot, dense state and has been expanding ever since (1); evidence, e.g. red shift of distant galaxies or the microwave background (1).

3 (a) Helium and calcium (1). (b) Different objects give out different types of radiation, so each type gives extra information (1).

About the author

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

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