ANSWER KEY — TEACHER COPY

Riding the Lift: Forces in Motion

All answers below are model responses. Accept reasonable variations where data-dependent.

C Phyphox Graph Analysis — Phase Annotation Table

The table below shows expected values based on the Phyphox image provided (L1 → L12 → L1, total ~93 s). Actual student values will vary slightly depending on their lift.

Phase	Time range (s)	Direction of a	v: increasing / constant / decreasing
L1 → L12: lift starts moving upward	~10–20 s	**Upward (+)**	Increasing
L1 → L12: constant speed upward	~20–40 s	**None (a = 0)**	Constant
L1 → L12: decelerates at L12	~40–45 s	**Downward (−)**	Decreasing
Stationary at L12	~45–60 s	**None (a = 0)**	Zero / stationary
L12 → L1: lift starts moving downward	~60–68 s	**Downward (−)**	Increasing (downward)
L12 → L1: constant speed downward	~68–85 s	**None (a = 0)**	Constant
L12 → L1: decelerates at L1	~85–93 s	**Upward (+)**	Decreasing

Q1 What does the flat plateau on the altitude graph represent? How long did the lift stay at Level 12?

Answer: The plateau represents the period when the lift is stationary at Level 12. The altitude is not changing, so the lift is neither moving upward nor downward.

Duration: Approximately 15 s (reading from ~45 s to ~60 s on the time axis). Accept any value between 10–20 s depending on actual lift dwell time.

Q2 From the velocity graph, estimate the lift's maximum speed in m s^{-1}. Show how you read this off the graph.

Answer: Maximum speed is the peak (flat top) of the velocity-time graph, read directly from the y-axis.

Expected value: Approximately 1.4–1.6 m s^{-1} (accept 1.2–1.8 m s^{-1}). Students should identify the plateau region of the v-t graph and read off the y-value, not attempt to differentiate the altitude graph manually.

Q3 The accelerometer data looks noisy compared to the altitude data. Why might this be?

Answer: The barometer measures air pressure, which changes slowly and smoothly with altitude — it acts as a natural low-pass filter, producing a clean signal. The accelerometer directly measures mechanical vibrations from the lift motor, cable, and building structure, so its signal contains high-frequency noise on top of the true acceleration signal.

> **Teacher Note:** Avoid accepting 'the accelerometer is less accurate' without further explanation. Guide students to the distinction between signal noise (precision) and systematic offset (accuracy).

Q4 At which two phases do you expect the scale to read below the person's actual weight? Explain using $N = m(g + a)$.

Phase 1: Decelerating when approaching Level 12 (moving upward, slowing down). Acceleration is directed downward, so $a < 0$.

Phase 2: Accelerating away from Level 12 toward Level 1 (starting to move downward, speeding up). Acceleration is again directed downward, so $a < 0$.

In both cases: $a < 0 \implies N = m(g + a) < mg \implies N < W \implies$ scale reads LESS than actual weight

💡 **Teacher Note:** Very common misconception: students say the scale reads less whenever the lift is 'going down'. Emphasise it is the direction of acceleration, not velocity, that determines N. During constant-speed downward travel, $a = 0$ and $N = W$.

D Weighing Scale & Slow-Motion Data

The table below shows expected scale readings for a 60 kg student (W = 600 N). Actual values depend on the lift's acceleration profile. The acceleration used here ($a \approx 0.4$ m s^{-2}) is a typical value for a passenger lift.

Phase	Scale (kg)	N = reading × 10 (N)	Expected: N > W, = W, or < W?	Matches theory?
Stationary at L1	60	600	**N = W**	Y
Accelerating upward	62.4	624	**N > W**	Y
Constant speed upward	60	600	**N = W**	Y
Decelerating at L12	57.6	576	**N < W**	Y
Stationary at L12	60	600	**N = W**	Y
Accelerating downward	57.6	576	**N < W**	Y
Constant speed downward	60	600	**N = W**	Y
Decelerating at L1	62.4	624	**N > W**	Y

💡 **Teacher Note:** Scale readings are calculated from N = m(g + a) ÷ g. With m = 60 kg and a = 0.4 m s^{-2}: N_{xp} = 60 × 10.4 = 624 N → 62.4 kg displayed. Accept readings within ±2 kg if student's lift has a slightly different acceleration.

Q5 Using the acceleration value from your Phyphox graph, calculate the expected N. Compare with your measured scale reading.

Given: m = 60 kg, g = 10 N kg^{-1}, a = 0.40 m s^{-2} (upward, from Phyphox v-t gradient during initial acceleration phase)

$$N = m(g + a) = 60 \times (10 + 0.40) = 60 \times 10.40 = 624 \text{ N}$$

Expected scale reading: 624 ÷ 10 = 62.4 kg

Measured reading (slow-motion): ~62 kg (typical)

Percentage difference: |(624 − 620)| ÷ 624 × 100% ≈ 0.6% — excellent agreement

💡 **Teacher Note:** Accept a values in the range 0.3–0.6 m s^{-2}. Students should read a from the gradient of the v-t graph (rise ÷ run over the acceleration phase) or from the Phyphox z-acceleration trace (averaged over the noisy region). Mark the method, not just the answer.

Q6 A 70 kg student is in a lift where the tension in the cable is 21,700 N and the combined mass of lift + passenger is 1,070 kg. Find the acceleration.

Given: T = 21,700 N, m_{total} = 1,070 kg, g = 10 N kg^{-1}

Weight of system: W = 1,070 × 10 = 10,700 N

$$F_{net} = T - W = 21{,}700 - 10{,}700 = 11{,}000 \text{ N (upward)}$$

$a = F_{net} \div m = 11{,}000 \div 1{,}070 \approx 10.3\ \text{m s}^{-2}$ (upward)

Interpretation: The net force is directed upward, so the lift is accelerating upward. It could be speeding up while moving upward, or slowing down while moving downward — both produce an upward acceleration.

Teacher Note: Some students may forget to include the mass of the lift in the calculation. The question states combined mass = 1,070 kg, so no further breakdown is needed. Award marks for correct method even if arithmetic is slightly off.

E Analysis & Discussion

Q7 Sketch a free body diagram for the Scale Person at each of the three key phases.

Award marks for: correctly labelled N and W arrows, correct relative lengths (proportional to magnitude), and correct inequality stated.

Phase	Free Body Diagram Description	Relationship
Accelerating upward	N arrow pointing UP (longer). W arrow pointing DOWN (shorter). Net force arrow pointing UP.	$N > W$ $N = m(g + a) = 60 \times 10.4 = 624$ N $W = 600$ N
Constant velocity	N arrow pointing UP. W arrow pointing DOWN. Both arrows EQUAL length. No net force.	$N = W$ $N = 600$ N $W = 600$ N
Decelerating (approaching L12)	N arrow pointing UP (shorter). W arrow pointing DOWN (longer). Net force arrow pointing DOWN.	$N < W$ $N = m(g + a) = 60 \times 9.6 = 576$ N $W = 600$ N

Teacher Note: The FBD must show forces acting ON the person only (N upward from scale, W downward due to gravity). Do not accept forces acting on the scale or the lift. Net force / resultant may be shown as a separate arrow or annotated beside.

Q8 A person feels 'heavier' when the lift accelerates upward. Explain using Newton's Second Law (3–4 sentences).

Model answer:

When the lift accelerates upward, a net upward force must act on the person. Applying Newton's Second Law (taking upward as positive): $N - mg = ma$, which gives $N = m(g + a)$. Since $a > 0$, N is greater than the person's weight mg. The weighing scale measures the normal contact force N acting on the person's feet, so it displays a value greater than the person's true weight, making them feel 'heavier'. The person's mass has not changed; only the contact force has increased.

Teacher Note: Deduct marks if students write 'weight increases'. The weight $W = mg$ is constant throughout. Only the normal contact force N changes. This is a critical distinction in H2 Physics.

Q9 If the lift cable snapped and the lift fell freely, what would the scale read? Justify with Newton's Second Law. What real-world phenomenon does this simulate?

In free fall: $a = -g = -10$ m s^{-2} (taking upward as positive)

$$N = m(g + a) = m(g - g) = m \times 0 = 0 \text{ N}$$

Scale reads: 0 kg. The scale displays zero because there is no contact force between the person and the scale.

Phenomenon simulated: Apparent weightlessness (also called microgravity). This is experienced by astronauts in orbit, who are in continuous free fall around the Earth.

Teacher Note: Students must NOT say 'gravity disappears' or 'weight = 0'. The gravitational force (weight) still acts on the person throughout free fall. It is the normal contact force N that becomes zero, not the weight. Gravity cannot be switched off.

Q10 Identify ONE limitation of the weighing scale method and ONE of Phyphox. Suggest one improvement for each.

Method	Limitation	Improvement
Weighing scale	Digital display updates slowly (typically 1 Hz), so the reading may lag behind the actual normal force during brief acceleration phases, causing underestimation of peak values.	Use a data-logging scale with a higher sampling rate (e.g. 10 Hz or more) and connect it wirelessly to record N vs. time continuously.
Phyphox (accelerometer)	The z-accelerometer signal is very noisy due to mechanical vibrations from the lift motor and cable, making it difficult to read the true acceleration accurately.	Apply a low-pass filter (available in Phyphox settings) to smooth the accelerometer signal, or use the barometer-derived velocity graph to calculate acceleration from the gradient instead.

F Group Reflection

Q11 Compare your Phyphox acceleration values with values derived from the scale readings ($a = N/m - g$). Do they agree? Discuss any discrepancies.

Derivation: From $N = m(g + a)$: $a = N/m - g$ = (scale reading × 10)/m − 10

Example (60 kg student, scale reads 62.4 kg during acceleration):

$$a = (62.4 \times 10) / 60 - 10 = 624/60 - 10 = 10.4 - 10 = 0.4 \text{ m s}^{-2}$$

Expected outcome: Values should agree to within ~10–15%. Likely sources of discrepancy: (1) scale display lag means the peak reading is lower than the true peak N; (2) Phyphox acceleration is noisy so students may over- or under-read the average.

💡 **Teacher Note:** Accept any reasoned comparison. Award marks for: correct rearrangement of formula, substitution of their own data, and a sensible discussion of why the two methods may differ.

Q12 Using your altitude graph, estimate the height of each floor. How does it compare to the standard 3.5 m per floor?

Method: Read the maximum altitude reached (approximately 42 m from the sample Phyphox image) and divide by the number of floors travelled.

Height per floor = Total altitude ÷ Number of floors = 42 m ÷ 12 ≈ 3.5 m per floor

Comparison: This matches the standard 3.5 m floor-to-floor height well. Some variation is expected because the barometer measures the altitude gain from Level 1, which may not start exactly at ground level, and the number of floors above ground may differ from 12 clear storeys.

💡 **Teacher Note:** Accept values in the range 3.0–4.0 m per floor. If a student's altitude maximum is different, check their arithmetic rather than penalising a reasonable reading.

Q13 Group consensus: Which method gave more reliable data — Phyphox or weighing scale? Give two reasons.

Expected consensus: Phyphox (barometer-derived altitude and velocity) gives more reliable data for this investigation.

- **Reason 1:** Phyphox records data continuously at a high sampling rate (barometer at ~100 Hz), capturing the full motion profile, whereas the weighing scale display updates at ~1 Hz and may miss peak values during brief acceleration phases.
- **Reason 2:** The Phyphox altitude and velocity graphs are smooth and clearly interpretable, allowing accurate identification of each phase and the maximum speed. The scale provides only a snapshot reading at each phase, which depends on the observer's ability to freeze-frame the footage at exactly the right moment.

💡 **Teacher Note:** Accept the opposite conclusion (scale more reliable) if supported by two valid reasons, e.g. 'the scale gives a direct force reading without derivation' and 'the barometer may drift with temperature'. Award marks for quality of reasoning, not the conclusion alone.

G Extension Challenge Answers

C1 A lift of mass 600 kg carries passengers totalling 300 kg. Cable tension = 10,350 N. Find the acceleration.

Total mass: 600 + 300 = 900 kg

Total weight: 900 × 10 = 9,000 N

$$F_{net} = T - W = 10{,}350 - 9{,}000 = 1{,}350 \text{ N (upward)}$$

$$a = F_{net} \div m = 1{,}350 \div 900 = 1.5 \text{ m s}^{-2} \text{ (upward)}$$

Interpretation: Net force is upward (+1.5 m s^{-2}). The lift is either speeding up while moving upward, or slowing down while moving downward. Both are consistent with an upward acceleration.

C2 Plot N vs time and overlay the acceleration-time graph. Describe the relationship between them.

Expected relationship: N and a are directly proportional (N = mg + ma = constant + m·a). The N-t graph has the same shape as the a-t graph, shifted upward by mg.

Key features to describe:

- **When a > 0 (upward):** N > mg. The N-t graph peaks above the baseline mg.
- **When a = 0:** N = mg. Both graphs sit at their respective baselines.
- **When a < 0 (downward):** N < mg. The N-t graph dips below the baseline mg.

N(t) = mg + m·a(t) ⟹ N-t graph is a vertically shifted, scaled version of the a-t graph

💡 **Teacher Note:** This is an excellent question for high-achieving students. The key insight is that N and a are linearly related through Newton's Second Law, with mg as the vertical offset. A student who plots both graphs and labels the correspondence correctly demonstrates deep conceptual understanding.

Key Equations

$F_{net} = ma$ | $N - mg = ma \implies N = m(g + a)$ | Scale-derived a: $a = N/m - g$ | Free fall: N = 0 | g = 10 N kg^{-1}