

Answer Key: Newton's Laws and Transportation Safety

Grade: 8 **Subject:** Science **For teacher use only** Science

How to use this key

Answers are grouped by section and question number. Many items are open-ended; accept any response that shows correct reasoning even if the wording differs. Notes flag where more than one answer is defensible and list common misconceptions to watch for. Estimated grading time: ~6–8 min per packet.

Start Notice & Wonder grade for effort · ~2 min

1 Riders lurch forward when a bus brakes hard.

Full credit for any reasonable notice + wonder. **Ideal:** Notice — "riders move forward even though nothing pushed them." Wonder — "why do we go forward when the bus goes forward and then stops?" Accept any on-topic wonder. *Science note (not required from students):* the riders' bodies have inertia and tend to keep moving forward (Newton's First Law) while the bus is being slowed by braking friction.

2 Two safety features + what they do.

Accept any two real features with a plausible purpose. Examples: seatbelt (holds you back / keeps you in the seat), airbag (cushions the head/chest), crumple zone (front of car folds to absorb the hit), headrest (stops the head snapping back). More than one answer is defensible.

Build Read the Science ~1 min

3 Which law explains the forward-tending body; name the property.

Newton's First Law (the law of inertia). The property shown by the dashed arrow is **inertia** — the body's tendency to keep moving forward at its original speed until a net force (like the seatbelt) slows it. Watch for students calling inertia "a force" — it is not (see misconceptions).

Apply Use the Data ~3 min

4 Observation (O) vs. Inference (I).

- a) **O** — a value read directly from the table (32 m).
 - b) **I** — it explains a cause ("because it spreads the stop over more time and area").
 - c) **O** — a value read directly from the table (2,700 N).
 - d) **I** — a reasoned conclusion about a consequence ("would be hurt worse").
- Observation = measured/read directly; inference = a conclusion reasoned from evidence.*

5 Which law explains each observation.

5a — First Law (inertia). The unbelted rider keeps moving forward because no net force acts on the body until something stops it.

5b — Second Law ($F = ma$). At the same braking force, more speed means the car must lose more motion, so it takes a longer distance/time to stop (accept reasoning that more speed $\rightarrow$ more distance for the same deceleration). Accept First Law reasoning only if a student clearly ties it to "more motion to change." Best answer is Second Law.

5c — Third Law (action–reaction). The belt pushes back on the rider and the rider pushes forward on the belt with an equal, opposite force on two different objects.

6 Compute with $F = ma$ (worked).

6a. $F = m \times a = 50 \text{ kg} \times 8 \text{ m/s}^2 = \mathbf{400 \text{ N}}$. (Full credit for correct setup and 400 N; accept units written as newtons.)

6b. $F = 80 \text{ kg} \times 8 \text{ m/s}^2 = \mathbf{640 \text{ N}}$. The **80 kg dummy needs the larger force** because it has more mass — for the same acceleration, more mass requires more force ($F = ma$). This is also more inertia to overcome. *Common error:* multiplying wrong or dropping units; a bare "640" with correct work still earns credit.

7 Which safety feature reduces force + why (worked examples).

Award full credit if the student names a feature *and* explains that it lowers the **peak force** by spreading the stop over more time or more area, tied to a Newton's law. Worked examples:

- **Seatbelt:** stretches slightly and holds the rider back so the body slows *with* the car over more time instead of hitting the dash suddenly. More stopping time $\rightarrow$ smaller acceleration $\rightarrow$ smaller force ($F = ma$). Table 1 shows belted forces are far lower than unbelted.
- **Crumple zone:** the front of the car folds and collapses, extending the crash over more time so the car (and rider) decelerate more gradually — lower acceleration, lower force ($F = ma$).
- **Airbag:** inflates to catch the head/chest, spreading the force over a larger **area** and more **time** than a hard dashboard, lowering the peak force.
- **Headrest:** stops the head from snapping backward (inertia, First Law) during a rear impact, reducing the sudden force on the neck.

Any feature earns credit if the "more time / more area $\rightarrow$ less force" mechanism and a law are correct.

Explain CER (Q8) ~2 min

8 Recommend one bus design change to improve safety.

Model answer. Claim: The city should require lap-and-shoulder seatbelts on its school buses. Evidence: (1) In Table 1, the peak force on the 50 kg dummy at 20 m/s was 4,000 N **with** a seatbelt but 10,500 N **without** — the belt cut the force to well under half. (2) In Figure 1, the seatbelt applies a backward force on the rider so the body slows with the car instead of continuing forward by inertia. Reasoning: By Newton's First Law, an unbelted rider keeps moving forward in a sudden stop; the belt provides the net force that stops the body more gradually, and by $F = ma$ a longer stopping time means a smaller acceleration and a smaller force on the rider.

Defensible alternates: A student may recommend crumple zones (extend crash time $\rightarrow$ lower acceleration $\rightarrow$ lower force, $F = ma$) or padded high seatbacks/headrests (catch the rider, spread force over more area/time). Accept any recommendation supported by two correct pieces of evidence and sound law-based reasoning. The seatbelt claim is strongest because Table 1 directly quantifies its effect.

CER scoring rubric (3 points)

Score	Claim	Evidence	Reasoning
3	Clear, specific design change stated.	Two accurate, relevant pieces from Table 1 and/or Figure 1.	Correctly links evidence to a Newton's law and explains why the force on riders drops.
2	Change stated, mostly clear.	One solid piece, or two with a minor error.	Some correct linkage but incomplete or a small misconception.

Score	Claim	Evidence	Reasoning
1	Vague or partly correct change.	Evidence weak, off-topic, or not from the sources.	Little or flawed reasoning; law not correctly named.
0	No/incorrect claim.	No evidence.	No reasoning.

Close ACE ~1 min

ACE Articulate / Connect / Extend.

Articulate: accept any accurate plain-language statement of one law (e.g., "things keep moving unless a force stops them" for the First Law).

Connect: the cited row/arrow must match the chosen law (e.g., inertia arrow → First Law; belted-vs-unbelted force column → Second Law, $F = ma$; the belt push/rider push pair → Third Law).

Extend: any correct new, out-of-vehicle example (e.g., First Law — a book stays on a table; Second Law — kicking a soccer ball harder makes it accelerate more; Third Law — a swimmer pushes water back and moves forward). More than one answer is defensible.

Extend Early finisher (optional)

EF Predict the effect of doubling speed / a heavier rider.

Reward reasoning over a single "right" number. **Doubling speed (10 → 20 m/s):** Table 1 shows the belted peak force rising from 1,600 N to 4,000 N — **more than double** (about 2.5×). Strong answers note that more speed means more motion to remove and, if stopping distance grows too, the force does not simply scale one-to-one; accept "more than double" with table support. **Heavier rider (50 → 80 kg) at the same speed and deceleration:** force increases in proportion to mass ($F = ma$), e.g., $80/50 = 1.6\times$ the force, because more mass means more inertia to stop. Do not require exact figures; require correct direction and an $F = ma$ / inertia justification.

Watch Common misconceptions

- **"Inertia is a force."** Inertia is a *property* (resistance to a change in motion) that depends on mass; it is not a push or pull and does not appear as a force arrow the way the seatbelt or braking friction do.
- **"Heavier always means more safety."** More mass means more inertia and needs a *larger* force to stop ($F = ma$). Mass alone does not protect a rider; features that extend the stopping time or area do.
- **"Action–reaction forces cancel out."** They are equal and opposite but act on **two different objects** (belt vs. rider), so they never cancel on the same object.
- **"Something pushes riders forward in a stop."** No forward force is added; the body simply continues forward by inertia (First Law) while the vehicle is slowed.
- **Observation vs. inference (Q4).** Students often mark a reasoned cause or consequence as an "observation." A "because..." or "would be..." statement is usually an inference.

Teacher follow-up based on likely errors

If many students call inertia a force (Q3), do a quick 5-minute sort of "force vs. property." If Q5 mixes up the laws, re-anchor each law to one arrow in Figure 1. If the $F = ma$ work in Q6 is shaky, model the setup $50 \times 8 = 400$ N aloud with units. If CER (Q8) evidence is thin, model citing a specific Table 1 pair (4,000 N vs. 10,500 N). The "action–reaction cancels" and "inertia is a force" misconceptions are the highest-value items to address next class.