

Substitute Guide: Newton's Laws and Transportation Safety

Grade: 8 **Subject:** Science **Time:** ~45 min core + ~15 min extension Science

Learning goal (plain language)

Students learn **Newton's three laws of motion** — **inertia** (things keep doing what they're doing), **$F = ma$** (net force equals mass times acceleration), and **action–reaction** (equal and opposite forces) — and use them to explain why car and bus safety features protect riders in a sudden stop. Working alone with a pencil, students read a short passage, study a labeled force diagram and a data table, do a small force calculation, and write an evidence-based design recommendation. **You do not need a science background to run this.** Everything students need is printed in their packet. This is a **paper** activity — no lab, no materials, no hazards.

Standards alignment

Framework: 19 TAC §112.28 (Grade 8 Science). Knowledge & skills on **force, motion, and Newton's laws**.

- **Provisional — 8.7 (Newton's laws):** apply Newton's three laws to describe and predict the motion of objects, including in transportation-safety situations.
- **Provisional — forces & $F = ma$:** calculate and interpret net force, mass, and acceleration using $F = ma$; distinguish balanced and unbalanced forces.

Provisional — pending educator verification against the current official TAC source. Codes and letters are placeholders until confirmed.

(Standards are paraphrased here, not quoted. Please confirm codes and wording against your official source. This packet is does not claim formal alignment to the TEKS.)

Setup Before class (5 min)

- Count and hand out one **student packet** per student.
- Confirm each student has a **pencil**. No calculators, computers, or lab items are needed (the $F = ma$ numbers are small and can be done by hand).
- Write the date on the board and remind students to fill in the name line.
- Keep the **answer key** with you — it is a separate file and is **not** in the student packet.

Materials What's needed

- Printed student packet (4–6 pages) per student.
- Pencil per student.
- This guide and the separate answer key (teacher only).
- No technology, no calculator, no lab equipment, no safety hazards.

Timing Suggested pacing (~45–60 min)

Segment	Time	What students do
Start — Notice & Wonder	5 min	Q1–Q2 warm-up
Build — Read the science	5–10 min	Read passage, word bank, force diagram; Q3
Apply — Use the data	20–25 min	Table 1; Q4–Q7 (includes an $F = ma$ calculation)
Explain — CER	5–10 min	Q8 design recommendation (claim/evidence/reasoning)
Close — ACE	5 min	Articulate / Connect / Extend
Continue — early finishers optional ~15 min		Predict what changes if speed or mass changes

Script Read aloud to start

"Today's assignment is a paper science investigation called *Newton's Laws and Transportation Safety*. You will work by yourself with just a pencil — no computers or calculators, and nothing to build or move. First read the short passage and study the force diagram and the data table. Then answer the questions in order; if one is tricky, skip it and come back. There is one small math step where you multiply mass times acceleration — the numbers are easy to do by hand. Write in complete sentences where it asks you to explain. You may quietly read the passage aloud to yourself. Put your name, class period, and date at the top now. You have about 45 minutes; raise your hand if you need help understanding a word."

Support When students ask for help

- **You may read any part aloud** to a student or the class.
- If they are stuck on "which law," point them to the **Newton's three laws** box and **Figure 1** — each arrow matches a law.
- For the $F = ma$ item (Q6), remind them the formula is printed: force = mass $\times$ acceleration, so 50×8 . They do not need a calculator.
- Encourage the printed **sentence stems** for the CER (Q8) and ACE sections.
- Do **not** give answers; prompt with "What does the data show?" or "Which arrow matches this?"
- It is fine if a student cannot finish the optional early-finisher task.

Access Accommodations & language support

- **Read-aloud** of any passage or question is allowed for all students.
- Point students to the **sentence stems** and the **Word Bank** (definitions provided).
- Extended time is fine; the core can stop after Q8 if time runs short.
- Students may answer in phrases if writing full sentences is a barrier, as long as the idea is clear. Showing the $F = ma$ multiplication is enough for Q6.
- The packet is grayscale-safe — it prints and reads clearly in black and white.

Tools Allowed & not allowed

Allowed: pencil, the printed packet, quiet self-read-aloud. **Not needed / not allowed:** calculator (the one math step is small), phones, computers, lab materials.

Collect at the end: Collect every packet, whether finished or not, with names on them. Stack them for the teacher. Note on a sticky how far most students got and any questions that caused confusion.

Answer key: The **answer key is a separate file** (answerkey.html) and is for the teacher only. Please do not hand it to students.

Teacher follow-up (for the returning teacher)

Watch for two high-value misconceptions: students calling *inertia a force*, and thinking *action–reaction forces cancel out*. A quick next-day discussion tying each of Newton's laws to one arrow in Figure 1, plus reviewing the observation-vs-inference item (Q4) and the $F = ma$ calculation (Q6), would reinforce this well. The CER (Q8) responses show who can cite the belted-vs-unbelted force data as evidence.

G08_SCI_NewtonSafety_01 — Newton's Laws and Transportation Safety Substitute Guide

Newton's Laws and Transportation Safety

Grade: 8 **Subject:** Science **Time:** ~45 min core + ~15 min extension **Work mode:** Independent · pencil only
Science

Start Here

This is a **paper investigation**. You will read a short passage, study a force diagram and a data table, and answer questions using a pencil. You do **not** need a computer, a lab, or any materials besides this packet and a pencil. There are **no hazards** — nobody moves or builds anything. Work by yourself and do your best thinking. Write in complete sentences where you are asked to explain. If a question is hard, skip it, keep going, and come back. Reading the passage quietly aloud to yourself is allowed and encouraged.

Start Notice & Wonder 5 min

Think about what your body feels when a moving vehicle suddenly slows or stops.

1A school bus is rolling forward at a steady speed when the driver hits the brakes hard. Riders feel themselves lurch **forward** in their seats even though nothing pushed them from behind. Write **one thing you notice** and **one thing you wonder** about this.

2Name **two safety features** in a car or bus that are meant to protect people during a sudden stop or a crash. For each one, say in a few words what you think it does.

Build Read the Science 5–10 min

Newton's three laws of motion

A **force** is a push or a pull. When several forces act on an object, they add up to a single **net force** — the overall push or pull once you combine them. If the forces balance (net force is zero), the object's motion does not change. Sir Isaac Newton described how forces and motion are connected in three laws:

- **First Law (inertia)** — an object keeps doing what it is doing (staying still, or moving at a steady speed in a straight line) **unless a net force acts on it**. **Inertia** is this tendency to resist a change in motion. Inertia is **not a force**; it is a property that every object with mass has. More mass means more inertia.
- **Second Law ($F = ma$)** — the **net force** on an object equals its **mass** times its **acceleration** (how quickly its speed or direction changes): $F = m \times a$. For the same mass, a bigger force causes a bigger acceleration. For the same force, more mass means less acceleration.
- **Third Law (action–reaction)** — for every force, there is an equal and opposite force. If object A pushes on object B, then B pushes back on A with the same size force in the opposite direction. These two forces act on **different objects**, so they do **not** cancel each other out.

Key idea for safety: in a sudden stop, the vehicle is pushed to a stop by braking friction, but a rider's body tends to **keep moving forward** because of inertia. Safety features work by applying forces that slow the rider more gently or spread the force out.

Word Bank

- force
a push or a pull on an object, measured in newtons (N).
- net force
the single overall force left after all forces are combined.
- inertia
an object's resistance to a change in its motion (not a force).
- acceleration
how quickly speed or direction changes, in m/s².
- action–reaction
paired forces, equal in size and opposite in direction, on two different objects.

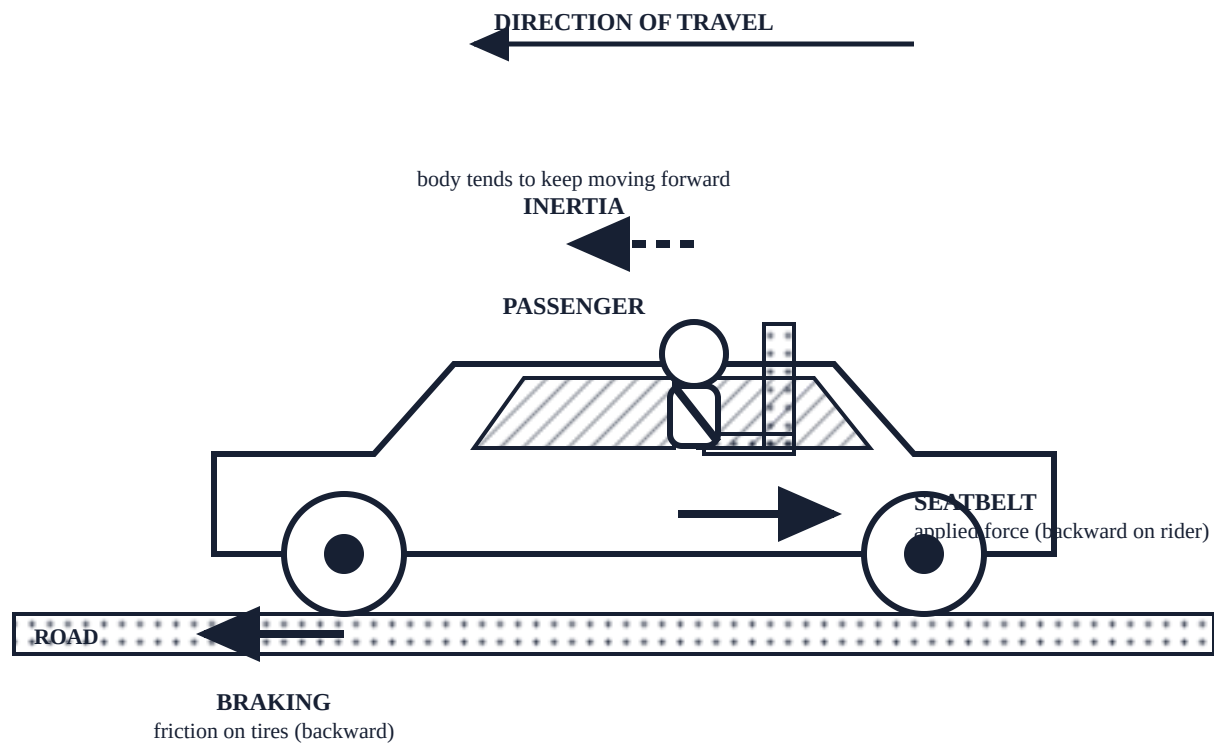


Figure 1. A car braking to a stop, seen from the side. The car moves to the left (direction of travel). **Braking friction** on the tires acts backward to slow the car. The passenger's body has **inertia**, so it tends to keep moving forward (dashed arrow). The **seatbelt** applies a backward force on the rider to slow the body with the car. Arrows and patterns — not color — carry the meaning, so the figure reads clearly in grayscale.

3In Figure 1, the passenger's body tends to keep moving forward during the stop. Which of Newton's three laws explains this, and what is the name of the property shown by the dashed arrow?

Apply Use the Data 20–25 min

A safety team recorded data from repeated braking tests using crash-test dummies. Study Table 1, then answer. (These are original numbers for this packet.)

Table 1. Braking-test data: stopping distance by speed, and peak force on a 50 kg dummy with and without a seatbelt (original data).

Starting speed (m/s)	Stopping distance (m)	Peak force on dummy — WITH seatbelt (N)	Peak force on dummy — NO seatbelt (N)
10	8	1,600	4,200
15	18	2,700	7,000

Starting speed (m/s)	Stopping distance (m)	Peak force on dummy — WITH seatbelt (N)	Peak force on dummy — NO seatbelt (N)
20	32	4,000	10,500

4Observation vs. inference. Read each statement. Write **O** if it is an observation (something directly measured or read from the table) or **I** if it is an inference (a conclusion you reason out).

- ____ a) At 20 m/s, the stopping distance was 32 m.
 ____ b) The seatbelt lowers the peak force because it spreads the stop over more time and area.
 ____ c) With a seatbelt at 15 m/s, the peak force was 2,700 N.
 ____ d) A rider with no seatbelt would be hurt worse because the force on their body is much larger.

5Which law explains each observation? For each, write First (inertia), Second ($F = ma$), or Third (action–reaction), and one short reason.

5a. When the brakes lock, the car slows but an unbelted rider keeps sliding forward until something stops them.

5b. At a higher starting speed, the same braking force produces a much longer stopping distance.

5c. As the seatbelt pushes back on the rider, the rider pushes forward on the seatbelt with an equal force.

6Compute with $F = ma$. During one stop, the 50 kg dummy decelerates (slows) at **8 m/s²**. Use **$F = m \times a$** to find the net force needed to stop it. Show your work.

6b. A larger 80 kg dummy is stopped at the same 8 m/s². Compute the net force for it. Which dummy needs a larger force, and why?

7Which safety feature and why. Pick ONE of these features — **seatbelt**, **crumple zone**, **airbag**, or **headrest** — and explain in 2–3 sentences **how it reduces the force felt by a rider**. In your answer, use the idea that spreading a stop over **more time** or **more area** lowers the peak force, and connect it to Newton's laws.

Explain Claim–Evidence–Reasoning 5–10 min

Question 8. A city is choosing **one design change** to make its school buses safer in sudden stops. As a young engineer, **recommend one change** (for example: require lap-and-shoulder seatbelts, add padded high seatbacks/headrests, or build in crumple zones). Write a claim, support it with **two pieces of evidence** from Table 1 or Figure 1, then explain your reasoning using Newton's laws.

Sentence stems you may use: "The city should... because..." · "One piece of evidence is... (from Table 1 / Figure 1)." · "A second piece of evidence is..." · "This reduces the force on riders because Newton's ____ Law says..."

Claim

Evidence (two pieces)

Reasoning

Close ACE Wrap-Up 5 min

Articulate

Explain **one** of Newton's laws (first, second, or third) in your own words, as if teaching a friend.

Connect

Point to one row of Table 1 or one arrow in Figure 1 that shows that law in action. Name it.

Extend

Give a **new** example of that law from somewhere *outside* of a car or bus.

Continue Early Finisher optional • ~15 min

If you finish early (no new materials needed):

Predict a change. On the back of this page, use $F = ma$ and Table 1 to reason about ONE change: *What would happen to the peak force on the dummy if the starting speed doubled from 10 m/s to 20 m/s?* Would the force roughly double, more than double, or stay the same? Use the numbers in Table 1 to support your prediction, then explain **why** using inertia and $F = ma$. Then predict how a **heavier** rider (say 80 kg instead of 50 kg) at the same speed would change the force, and why.

Turn in: Hand in this whole packet with your name, class period, and date filled in. Make sure questions 1–8 and the ACE box are answered. The early-finisher prediction is optional but turn it in too if you did it.

G08_SCI_NewtonSafety_01 — Newton's Laws and Transportation Safety Student Packet



TEACHER ANSWER KEY FOLLOWS

Do not copy the pages after this divider for students.

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 $2.5\times$). 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.