

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.

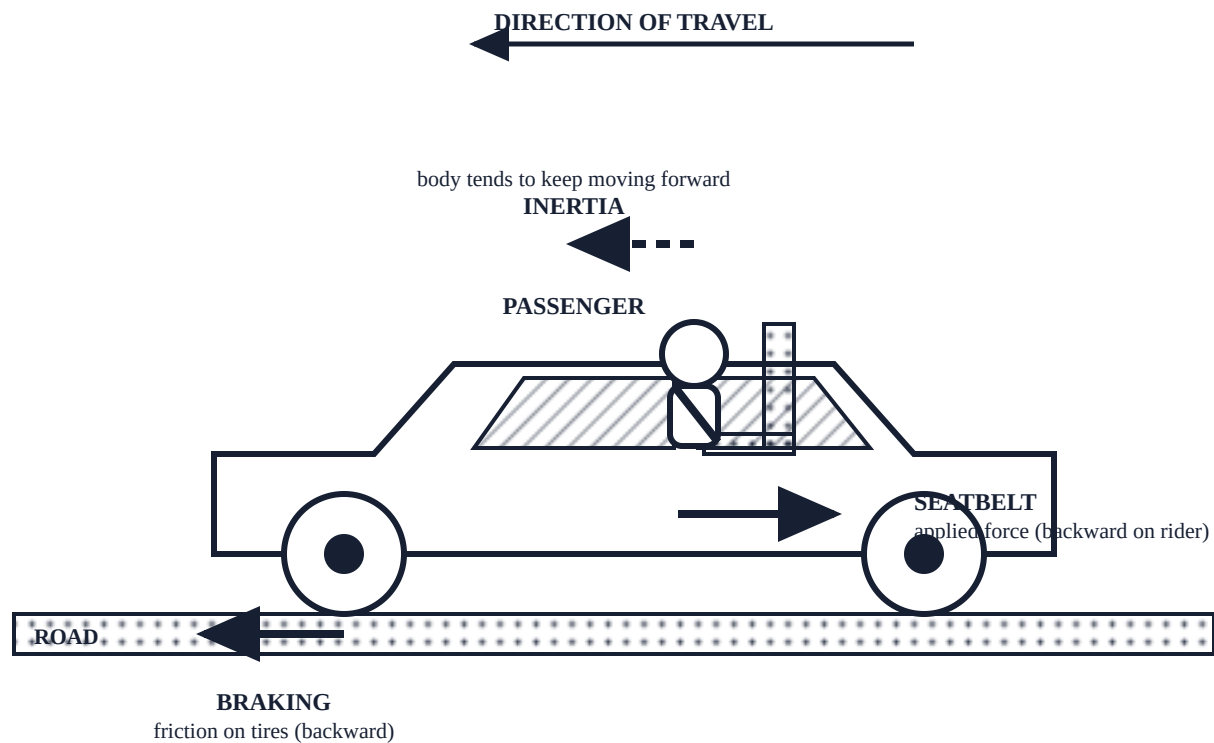


Figure 1. A car braking to a stop, seen from the side. The car moves to the left (direction of travel). **Braking friction** on the tires acts backward to slow the car. The passenger's body has **inertia**, so it tends to keep moving forward (dashed arrow). The **seatbelt** applies a backward force on 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