Push Harder or Load Heavier?

Teacher		**Class**	Grade 8
Subject	Science	**Topic**	Newton's laws of motion
Date		**Room**	
Lesson length	60 minutes	**Country**	United States

Students learn that change in motion depends on net force and mass. They plan and run fair cart tests and use timed evidence.

Curriculum links

- Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- Work, force, and motion are related [1]

Learning objectives

- Students will plan a fair test that changes net force and mass.
- Students will collect timed evidence showing how motion changes.
- Students will explain that acceleration depends on net force and mass.

Success criteria

- I can keep variables fair and change only force or mass.
- I can use timed results as evidence of changed motion.
- I can link net force and mass to size of acceleration.

What students already know

Ask: What makes a rolling toy speed up, slow down, or turn? Listen for push, pull, and friction ideas in 2 minutes.

Key words

net force	sum of all pushes and pulls acting together [17]
mass	amount of matter in an object, measured in kilograms [14]
acceleration	how quickly speed or direction of movement changes [14]
friction	rubbing push or pull that opposes sliding and slows movement [23]

Materials

- toy cars or carts
- spring scales
- extra masses
- meter sticks
- stopwatches
- tape
- Slides 1-7, 9, 11-12
- Video clip 1 (0:00-2:03) on Slide 6
- Worksheet Tasks B, C, F - one copy per student

Before the lesson

- Print Worksheet Tasks B, C, F and the pre-made data table for each group
- Test Video clip 1 (0:00-2:03) on Slide 6 for sound and captions
- Set up 2-meter taped track, meter sticks, cars, spring scales, and masses at stations
- Check stopwatches and mark start and finish lines

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- pre-made data table with pull, added mass, time, observations
- whiteboards or paper for claims

Lesson outline

0–8 min **Starter** 8 min · Whole class

Connect prior push and pull ideas to the question of proving motion change.

YOU DO

1. Show Slide 1 Push, Pull, and Speed Up and say the hook question.
2. Show Slide 5 mystery: same push on an empty cart and a full cart.
3. Take a vote on which speeds up more and ask for reasons.
4. Link answers to learning goal: plan a fair test of force size and mass.

STUDENTS DO

1. Vote empty cart or full cart for bigger speed-up.
2. Share with neighbor why mass might matter.
3. Share one idea for how to prove motion changed.

Say: If I push a shopping cart gently and then really hard, how do we prove the motion really changed? Today we will plan a fair test of pushes and mass and collect evidence.

Ask: Same push on an empty cart and a full cart. Which speeds up more? (The empty one. Same net force moves smaller mass faster.) · How could we prove the motion changed? (Time it over 2 meters or describe speed change.)

Check understanding: Hands up for empty vs full; if split, restate Slide 5 answer and ask one student to repeat it.

Support: Offer sentence frame: The ___ will speed up more because ___. **Stretch:** Ask why keeping the push the same makes the empty vs full test fair.

Use: Slides 1, 5

8–20 min **Teaching** 12 min · Whole class

Explain that net force changes motion and mass resists change.

YOU DO

1. Show Slide 3 chain: unbalanced pushes add to net force, net force changes speed or direction, mass resists change [3].
2. Show Slide 4 statement: change in motion comes from net force, and mass slows it down.
3. Play Video clip 1 on Slide 6 and pause to name net force as the sum [17].
4. Model F = ma calculation with 1-kg and 2-kg example [8].

STUDENTS DO

1. Watch clip and note one example of bigger push and one of added mass.
2. Copy chain and work the 4 N numbers with teacher.
3. Say back the rule: bigger net force means bigger change, bigger mass means smaller change [8].

Say: Unbalanced pushes add up to net force. Net force changes speed or direction. More mass resists that change. Result: acceleration depends on both force and mass.

Worked example: Push with net force 4 N. For mass 1 kg, acceleration = 4 / 1 = 4 m/s2. For mass 2 kg with same 4 N, acceleration = 4 / 2 = 2 m/s2. Same force, bigger mass means smaller acceleration [8].

Ask: What is net force? (The sum of all pushes and pulls acting on the object.) · Same mass, double the push. What happens to acceleration? (Acceleration doubles, because force equals mass times acceleration [8].) · Same push, double the mass. What happens? (Acceleration is half as large; mass resists change [3].)

Check understanding: Mini-whiteboards: write what doubles when push doubles; reteach F = ma if many write mass.

Support: Provide arrow cards of different lengths to show small vs large net force before drawing. **Stretch:** Ask students to predict what tripling force does to acceleration for the same mass.

Use: Slides 3-4, Slide 6 + Video clip 1 (0:00–2:03)

20–30 min **Planning** 10 min · Groups

Plan a fair two-part test for force size and for mass.

YOU DO

1. Show Slide 7 steps: keep ramp, cart, and distance same; Test 1 change pull with 1, 2, 3 bands; Test 2 same pull with added 500-g masses.
2. Model how to read spring scale and time each run over 2 meters, repeat twice.
3. Hand out Worksheet Tasks B and C and pre-made data table.
4. Assign roles: puller, timer, recorder.

STUDENTS DO

1. Draw setup in Worksheet Task C with start line, finish line, pull arrow, and masses.
2. Complete Worksheet Task B plan listing variables to keep the same.
3. Practice reading spring scale together to 0.5 N.

Say: We keep everything the same except what we test. First we change the pull. Then we keep the pull the same and change the mass. We time each run and repeat twice.

Worked example: Fair plan: Track 2 meters. Test 1: same car, pulls of 1 N, 2 N, 3 N. Test 2: same 2 N pull, masses of 0 g, 500 g, 1000 g. Only one thing changes at a time.

Ask: In Test 1, what do we change and what do we keep the same? (Change pull strength; keep mass, car, distance, surface same.) · In Test 2, what do we change and what do we keep the same? (Change mass; keep pull, car, distance, surface same.)

Check understanding: Collect Task C sketches for start, pull, mass labels; fix missing controls before testing.

Support: Give pre-made data table with columns for pull, added mass, time, and observations so students focus on controlling variables. **Stretch:** Have students predict what doubling the pull should do to acceleration, then test it and explain using force equals mass times acceleration [8].

Use: Slide 7, Worksheet Tasks B-C

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30–50 min **Main activity** 20 min · Groups

Collect timed evidence that motion change depends on force and mass.

YOU DO

1. Show Slide 9 task and start timer for Test 1: three pulls, same mass, time to travel 2 meters.
2. Circulate to check steady pulls, fair release, and two repeats.
3. Switch groups to Test 2: same pull, three masses, time each run.
4. Prompt claim writing: bigger net force means bigger change, bigger mass means smaller change [8].

STUDENTS DO

1. Run Test 1 with three pull strengths and record times twice each.
2. Run Test 2 with zero, one, and two masses and record times twice each.
3. Write a claim using pattern: bigger net force, bigger change; bigger mass, smaller change.

Say: Run Test 1 and record roll times. Run Test 2 and record roll times. Table your results and decide what changed the motion. Use your times as evidence.

Worked example: Group result: 1 N pull = 3.2 s, 2 N pull = 2.1 s, 3 N pull = 1.6 s over 2 meters. Same car. Faster time means larger speed gain, so larger net force gave larger acceleration. With 2 N pull: 0 g = 2.1 s, 500 g = 2.8 s, 1000 g = 3.5 s, so added mass slowed change [3].

Ask: Your time got shorter when pull increased. What does that show? (Bigger net force caused bigger acceleration and larger velocity change.) · Your time got longer when mass increased. What does that show? (Bigger mass resists change, so same force gives smaller acceleration [3].)

Check understanding: Check tables for two repeats and correct trend; ask group to rerun one trial if times vary widely.

Support: Mark start and finish lines and assign roles so one student releases, one times, and one records.
Stretch: Ask students to explain why they must keep ramp height or surface the same and what raising it would do to net force.

Use: Slide 9

50–60 min **Plenary** 10 min · Whole class

Share claims and check that net force and mass explain acceleration.

YOU DO

1. Show Slide 11 question: two students push a desk opposite ways, when does it move?
2. Take 2 group claims and link to unbalanced force changing motion [3].
3. Show Slide 12 quiz and run Worksheet Task F for claim plus evidence.
4. Preview exit check and collect Task F.

STUDENTS DO

1. Think, pair, share Slide 11 answer with neighbor.
2. Answer Slide 12 quiz on whiteboards.
3. Complete Worksheet Task F with claim and two numbers as evidence.

Say: If pushes are balanced, motion does not change. If one push is stronger, the sum is not zero and the desk accelerates. That sum and the mass decide the change.

Ask: Two students push a desk opposite ways. When does it start moving? (It starts moving when pushes are unbalanced. A tug of war with equal pulls is balanced with zero acceleration [14].) · Net force is zero. What happens to motion? (No change - stays still or keeps same velocity.)

Check understanding: Exit whiteboards for quiz; if many miss net force zero, redraw opposite equal arrows summing to zero.

Support: Highlight two key rows for comparison and give sentence frames for claim and evidence. **Stretch:** Ask what other opposite force is missing that also changes the sum, listening for friction [23].

Use: Slides 11-12, Worksheet Task F

Common mistakes

Mistake	How to spot it	How to fix it
Thinking heavier objects always speed up more or fall faster with same push.	Claims that added mass gave larger acceleration despite longer times.	Point to data and restate that acceleration depends on mass and force applied, so same force on larger mass gives smaller acceleration [3].
Thinking balanced forces cause motion change.	Says desk moves when opposite pushes are equal.	Draw equal opposite arrows summing to zero and show velocity stays constant unless acted on by an unbalanced force [3].
Mixing up mass and force effects in F = ma.	Predicts doubling mass doubles acceleration.	Use numbers: 4 N on 1 kg = 4 m/s2, on 2 kg = 2 m/s2, because force equals mass times acceleration [8].

Support

- Give pre-made data table with columns for pull, added mass, time, and observations so students focus on controlling variables.
- Provide arrow cards and partly drawn setup to build force picture before drawing.

Stretch

- Have students predict what doubling the pull should do to acceleration, then test it and explain using force equals mass times acceleration [8].
- Ask what happens with three pulls at once and how friction changes the sum of forces [23].

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For the LSE or teaching assistant

Stay with target groups during planning and testing: help read spring scale, keep timing fair, and prompt claim frames using time evidence.

Check for understanding

Question	Answer
Net force is zero. What happens to the motion?	No change - stays still or keeps same speed and direction.
Same mass, you double the net pull from 2 N to 4 N. What happens to acceleration?	Acceleration doubles.
Same 2 N pull, you double the mass. What happens to the change in motion?	Change is smaller; acceleration is half as large.

Homework

Write a paragraph explaining your cart results using net force, mass, and acceleration.

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