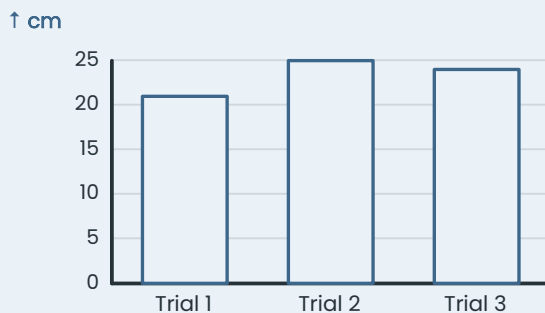


Forces & Motion Data Lab: Rover Test Track

6 complete activities from Forces & Motion Data Lab, each with a worked answer.



Trial	cm
1	21
2	25
3	24

HOW TO USE

1. Read the situation and the evidence first.
2. Show your thinking in the work boxes, not only an answer.
3. Explain how you know your answer makes sense.
4. Try the new problem at the bottom of the page.

6 activities • 3 answer pages • From the 24-activity collection

10 US Letter pages • Print at 100% / Actual Size

Original Bobotemp educational printable • Fictional names, places and prices

Name _____ Date _____

LEVEL 1



Read each card from the pretend Rover Team's notebook. These observations were already recorded. Nothing needs to be built or tested.

The Rover Team wrote six observation cards. For each card, decide whether the force is a push or a pull. Decide by the direction of the force, not by the direction the object moves. A push is a force that points away from whoever acts, like pressing on something. A pull is a force that points toward whoever acts, like tugging a rope. Then name the motion change: start, stop, speed up, slow down, or change direction. Use your sorting to find the one card that shows a pull that made an object slow down.

ROVER TEAM OBSERVATION CARDS

Card A

Kai's hand presses on a resting wagon, away from him. The wagon starts to roll.

Card B

Lena stands on the dock and tugs a string tied to a resting toy boat, toward herself. The boat starts moving.

Card C

Rosa's foot presses against the side of a rolling ball, away from her. The ball changes direction.

Card D

A sled slides away from a helper. The helper tugs the sled's rope back toward herself. The sled keeps sliding away from her but slows down.

Card E

A cart rolls toward Sam. Sam's hand presses on the front of the cart, away from him. The cart keeps rolling toward him but slows down.

Card F

A steel marble rolls past a magnet. The magnet tugs the marble toward itself. The marble turns.

1. Label each card Push or Pull.

2. Write the motion change for each card.

[illegible]

3. Which card shows a pull that slowed an object down?

TRY IT • A notebook says: 'Mia tugs a rope tied to the side of a rolling wagon, toward herself, and the wagon curves.' Is this a push or a pull, and what motion change happens?

Name _____ Date _____

LEVEL 1



Look at the four force diagrams a pretend team drew. Each arrow is labeled with its size in force units and its direction.

The team drew four force diagrams for a box on a flat floor. Compare the arrow sizes listed for each diagram. If the arrows are equal, the forces are balanced and the box's motion does not change. If the arrows are not equal, subtract to find the net force, and point it toward the larger arrow. Which diagram has the largest net force?

ARROWS ON A BOX (LONGER ARROW = LARGER FORCE; DOT = BOX)

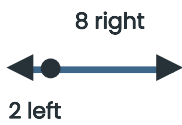


Diagram A

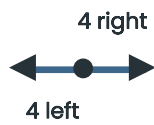


Diagram B



Diagram C



Diagram D

1. Label each diagram balanced or unbalanced.

2. Find the net force and direction for each unbalanced diagram.

[illegible]

3. Which diagram has the largest net force?

[illegible]

TRY IT • A diagram shows 6 units up and 6 units down on a hanging sign. Are the forces balanced or unbalanced? What is the net force?

Name _____ Date _____

LEVEL 2



Read the pulls from a pretend class's tug-of-war force diagram. Each number is one team member's pull in force units.

A fictional class drew a tug-of-war diagram and listed the size of each arrow below. Each arrow shows one team member's pull in force units. Find each team's total pull. Then find the net force on the rope and the direction in which the rope's motion will change.

PULLS ON THE ROPE (FORCE UNITS)

Left team

4	6	5
---	---	---

total ?

Right team

3	7	3	4
---	---	---	---

total ?

EVIDENCE TO USE

- Left team arrows: 4, 6, 5 units
- Right team arrows: 3, 7, 3, 4 units
- The rope starts at rest.

1. Find the total pull for each team.

2. Are the forces balanced or unbalanced?

3. Find the net force and its direction.

TRY IT • Left arrows are 8, 2, and 5 units. Right arrows are 6, 6, and 3 units. Are the forces balanced or unbalanced?

Name _____ Date _____

LEVEL 2



A pretend wagon team mixed units in its notes. Convert to one unit before you add or compare.

A fictional wagon team recorded three runs but mixed meters with centimeters and minutes with seconds. Convert every distance to centimeters before adding ($1\text{ m} = 100\text{ cm}$). Convert times to seconds ($1\text{ min} = 60\text{ s}$). Find the total distance of all three runs in centimeters, and decide which run took the longest.

WAGON RUNS: CONVERT FIRST

Run	Recorded	Distance (cm)	Time (s)
Run 1	2 m in 1 min	?	?
Run 2	150 cm in 75 s	?	?
Run 3	3 m in 2 min	?	?

EVIDENCE TO USE

- Run 1: 2 m in 1 min
- Run 2: 150 cm in 75 s
- Run 3: 3 m in 2 min
- 1 m = 100 cm
- 1 min = 60 s

1. Convert each run's distance to centimeters.

[illegible]

2. Find the total distance in centimeters.

[illegible]

3. Convert each time to seconds. Which run took the longest?

TRY IT • One run lasted 4 min. Another lasted 230 s. Which run was longer, and by how many seconds?

Name _____ Date _____

LEVEL 3



Compare three pretend rovers fairly by finding how far each moved in one second.

Three fictional rovers each moved at a steady pace on a test track, but the team timed them for different numbers of seconds. To compare them fairly, find how many meters each rover moved in each second. Then rank the rovers from fastest to slowest, and explain why the greatest total distance does not decide the winner.

STEADY-PACE ROVERS

Rover	Distance	Time	Meters each second
Red	56 m	7 s	?
Blue	63 m	9 s	?
Green	54 m	6 s	?

EVIDENCE TO USE

- Rover Red: 56 m in 7 s
- Rover Blue: 63 m in 9 s
- Rover Green: 54 m in 6 s
- Each rover kept a steady pace the whole time.

1. Find the meters each second for each rover.

2. Rank the rovers from fastest to slowest.

A blank sheet of graph paper with a grid pattern. The grid consists of 10 columns and 10 rows of squares. The lines are light gray and form a uniform grid across the page.

3. Explain why the rover with the greatest total distance is not the fastest.

TRY IT • Rover Gold moved 72 m in 8 s at a steady pace. Where does it fit in the ranking?

Name _____ Date _____

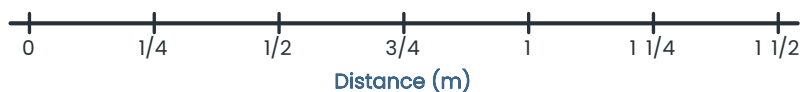
LEVEL 3



Make a line plot in fourths from a pretend team's marble trials. Then add and subtract the fractions.

A fictional team recorded how far a marble rolled after leaving a tube in five trials. Each distance was measured to the nearest quarter meter. Make a line plot from 0 to $1\frac{1}{2}$ m marked in fourths. Then find the total distance of all five trials and how much farther the longest roll went than the shortest.

LINE PLOT: MARBLE ROLLS



EVIDENCE TO USE

- Trial distances (m): $1/2$, $3/4$, $1\frac{1}{4}$, $3\frac{3}{4}$, $1\frac{1}{4}$
- Line plot: 0 to $1\frac{1}{2}$ m, marked in fourths

1. Place an X for each trial on the line plot.

2. Find the total distance of all five trials.

A blank sheet of graph paper with a grid of squares. The grid consists of 10 columns and 8 rows of squares. The paper has rounded corners and a light gray border.

3. How much farther was the longest roll than the shortest?

TRY IT • New trials: $\frac{1}{4}$, $\frac{1}{2}$, $\frac{1}{2}$, and 1 m. What is the total distance?

1. Push or Pull? Observation Cards

LEVEL 1

Card D. Pushes: A (start), C (change direction), E (slow down). **Pulls:** B (start), D (slow down), F (change direction).

WORKED REASONING • Look at the direction of each force compared with whoever acts. Pulls point toward whoever acts: B (string tugged toward Lena), D (rope tugged back toward the helper), and F (marble tugged toward the magnet). Pushes point away from whoever acts: A (away from Kai), C (away from Rosa), and E (away from Sam). The slow-down cards are D and E. In Card D, the sled is still moving away from the helper, but her force points toward her, so it is a pull. In Card E, the cart is still moving toward Sam, but his hand presses away from him, so it is a push. The only card on both the pull list and the slow-down list is Card D.

WATCH FOR • Some students decide push or pull by the way the object moves, or they think a push always speeds things up. Card E shows a push that slows a cart that is still rolling toward the hand, because the push points opposite the cart's motion. Push and pull name the direction of the force. Whether a force speeds an object up or slows it down depends on the force's direction compared with the motion, not on whether it is a push or a pull.

TRANSFER • It is a pull, because the force points toward Mia, and the wagon changes direction.

2. Arrow Count: Balanced or Not

LEVEL 1

Diagram C has the largest net force: 7 units left. The others are A: 6 units right, B: balanced (0), and D: 3 units right.

WORKED REASONING • A: $8 - 2 = 6$. The net force points toward the bigger arrow, so it is 6 units right (unbalanced). B: 4 and 4 are equal, so the forces are balanced and the net force is 0. C: $9 - 2 = 7$, so the net force is 7 units left (unbalanced). D: $10 - 7 = 3$, so the net force is 3 units right (unbalanced). Comparing 6, 0, 7, and 3, the largest is 7, in Diagram C.

WATCH FOR • Students may add opposite arrows ($2 + 9 = 11$) instead of subtracting. Opposite arrows work against each other, so subtract the smaller from the larger and point the net force toward the larger arrow. Balanced does not mean 'no forces.' Diagram B has two forces that cancel.

TRANSFER • The forces are balanced. The net force is 0 units, so the sign's motion does not change and it stays still.

9. Tug-of-War Diagrams

LEVEL 2

The left team pulls 15 units and the right team pulls 17 units. The forces are unbalanced. The net force is 2 units to the right, so the rope starts moving right.

WORKED REASONING • Left: $4 + 6 + 5 = 15$ units. Right: $3 + 7 + 3 + 4 = 17$ units. Because 15 and 17 are not equal, the forces are unbalanced. Net force: $17 - 15 = 2$ units toward the larger side, which is right. The rope starts moving to the right.

WATCH FOR • Students may think the team with more people always wins, or they may compare only the biggest arrows (6 vs. 7). The net force depends on the total of all the arrows on each side. Here the four-person side wins only because its total is larger.

TRANSFER • Left: 15 units. Right: 15 units. The forces are balanced and the net force is 0, so the rope's motion does not change.

10. Conversion Station

LEVEL 2

The total distance is 650 cm ($200 + 150 + 300$). Run 3 took the longest at 120 s. Run 1 took 60 s and Run 2 took 75 s.

WORKED REASONING • Run 1: $2 \times 100 = 200$ cm. Run 2 is already 150 cm. Run 3: $3 \times 100 = 300$ cm. Total: $200 + 150 + 300 = 650$ cm. Times: Run 1 is $1 \times 60 = 60$ s, Run 2 is 75 s, and Run 3 is $2 \times 60 = 120$ s. Comparing 60, 75, and 120, Run 3 took the longest.

WATCH FOR • Adding the numbers as written ($2 + 150 + 3 = 155$) mixes units and gives a wrong total. Another error is thinking Run 3's 2 min is shorter than Run 2's 75 s because $2 < 75$, without converting. In fact, 2 min = 120 s, which is longer than 75 s. Convert everything to the same unit before adding or comparing.

TRANSFER • $4 \times 60 = 240$ s, and $240 - 230 = 10$ s. The 4 min run was longer by 10 s.

17. Distance Each Second

LEVEL 3

Rover Green is fastest at 9 m each second ($54 \div 6 = 9$). Rover Red moves 8 m each second and Rover Blue moves 7 m each second. From fastest to slowest: Green, Red, Blue.

WORKED REASONING • Red: $56 \div 7 = 8$ m each second. Blue: $63 \div 9 = 7$ m each second. Green: $54 \div 6 = 9$ m each second. Since $9 > 8 > 7$, the order is Green, Red, Blue. Blue had the greatest total distance (63 m) only because it was timed the longest (9 s).

WATCH FOR • Students may rank by total distance and call Blue the fastest. Totals from different amounts of time cannot be compared directly. Finding the distance in each single second puts every rover on equal terms.

TRANSFER • $72 \div 8 = 9$ m each second, so Gold ties Green for fastest.

18. Fraction Line Plot

LEVEL 3

The total is $3 \frac{1}{2}$ m (3.5 m). The longest roll minus the shortest roll is $1 \frac{1}{4} - \frac{1}{4} = 1$ m. The mode is $\frac{3}{4}$ m.

WORKED REASONING • Rename each distance in fourths: $\frac{2}{4}$, $\frac{3}{4}$, $\frac{1}{4}$, $\frac{3}{4}$, $\frac{5}{4}$. Add the numerators: $2 + 3 + 1 + 3 + 5 = 14$, so the total is $\frac{14}{4} = 3 \frac{2}{4} = 3 \frac{1}{2}$ m. The longest roll is $\frac{5}{4}$ and the shortest is $\frac{1}{4}$, so $\frac{5}{4} - \frac{1}{4} = \frac{4}{4} = 1$ m. Two Xs stack at $\frac{3}{4}$, so the mode is $\frac{3}{4}$ m.

WATCH FOR • Students may add both the numerators and the denominators ($\frac{1}{2} + \frac{3}{4} = \frac{4}{6}$). Denominators name the size of the parts, so they must match first; then add only the numerators. Also, place $\frac{1}{2}$ at the same mark as $\frac{2}{4}$.

TRANSFER • $\frac{1}{4} + \frac{2}{4} + \frac{2}{4} + \frac{4}{4} = \frac{9}{4} = 2 \frac{1}{4}$ m.