Forces on a Sled

Read how changing forces change a free-body diagram.

P.2.d "Create an explanation of the nature of forces and the interactions among them, including tension, friction, gravitation, and normal forces, using free-body diagrams."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline the four force names, circle words that show their directions, and number the three motion stages in order so you can track how the sled's diagram changes.

A Supply Sled on Snow

1. At a winter festival, a volunteer pulls a supply sled across a level, snowy path with a rope held parallel to the ground. To predict its motion, treat the sled as the system and draw a free-body diagram: a dot for the sled and one arrow for each external force acting on it. The rope pulls the sled forward through tension. Sliding contact with the snow produces friction that points backward, opposing the sled's motion. These arrows describe forces on the sled, not the forces the sled exerts on the rope or snow.

2. Gravity pulls the sled downward toward Earth, while the snow pushes upward on the sled with a normal force. Normal means perpendicular to the contact surface, so it points straight up on this level path. The sled does not rise or sink, so these vertical forces balance: their arrows should have equal lengths. The snow also pushes horizontally through friction; this is a separate force from the upward normal force. In a free-body diagram, each arrow starts at the dot, points in the force's direction, and carries a label identifying its source or type.

3. At first, the volunteer pulls hard enough that the sled speeds up. Its forward tension arrow must be longer than its backward friction arrow because the net horizontal force points forward. Later, the sled slides at a constant speed while the volunteer still pulls. Now the two horizontal arrows have equal lengths, even though both forces still act. If the volunteer lets go while the sled is moving, the rope no longer pulls. Friction remains directed backward until the sled stops, so the sled slows. A free-body diagram changes when an interaction begins or ends.

2 ANSWER WITH EVIDENCE

Use the passage

1. How do the two horizontal arrows differ when the sled speeds up, and how should they compare when it moves at constant speed?

2. A classmate adds a backward arrow labeled “sled pulls rope” to a free-body diagram of the sled. Should that arrow be there? Explain.

3. Even while the sled speeds up, why should its gravity and normal-force arrows have equal lengths?

4. After the volunteer lets go, which force arrow disappears from the sled’s diagram? Which horizontal arrow remains, and what happens to the sled?

3 YOUR TURN

Your own words

A traveler pulls a plastic bin across a level floor at constant speed using a rope that slopes upward in the direction of travel. In the box, draw a free-body diagram of the bin with four labeled force arrows, then write two sentences explaining how its horizontal and vertical forces balance.

Forces on a Sled

PART 1 · READ AND MARK

Underline the four force names, circle words that show their directions, and number the three motion stages in order so you can track how the sled's diagram changes. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	How do the two horizontal arrows differ when the sled speeds up, and how should they compare when it moves at constant speed?	**While the sled speeds up, the forward tension arrow is longer than the backward friction arrow. At constant speed, they are equal in length.**
2	A classmate adds a backward arrow labeled "sled pulls rope" to a free-body diagram of the sled. Should that arrow be there? Explain.	**No. The diagram shows forces acting on the sled, not a force the sled exerts on the rope.**
3	Even while the sled speeds up, why should its gravity and normal-force arrows have equal lengths?	**The sled does not rise or sink, so the upward normal force balances the downward gravitational force.**
4	After the volunteer lets go, which force arrow disappears from the sled's diagram? Which horizontal arrow remains, and what happens to the sled?	**The tension arrow disappears. Backward friction remains, causing the moving sled to slow.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

Diagram: a dot with tension pointing up and forward, friction pointing backward, normal force pointing up, and gravity pointing down. The forward part of tension balances friction because the bin moves at constant speed. The upward part of tension and the normal force together balance gravity because the bin stays at the same height.

Accept diagrams with arrows starting at the bin and the four correct directions. Arrow lengths need not be exact, but the explanation must account for the upward part of the angled tension force.