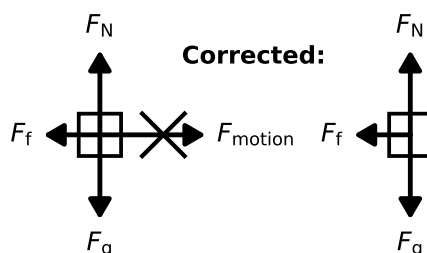


Part A: Reading Free-Body Diagrams

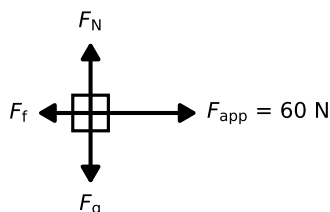
1. Ana drew this free-body diagram for a soccer ball that rolls to the right across the grass and slows down. Find the mistake in her diagram and explain how to fix it.



The **F_{motion} arrow is wrong**. Nothing touches the ball from behind, so there is no forward force. Moving objects do not carry a "force of motion" with them; the ball keeps rolling because of inertia.

Fix: erase F_{motion} . Keep F_N up, F_g down (equal), and F_f to the left.

2. The free-body diagram below is drawn to scale. The F_{app} arrow stands for 60 N.

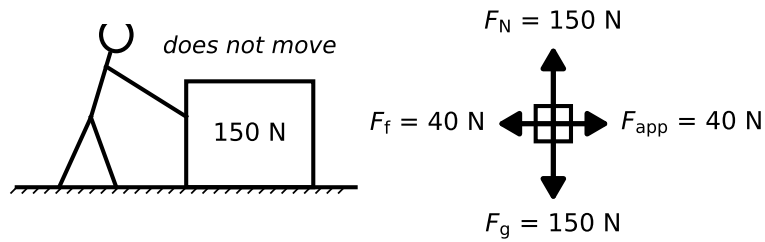


- About how large is the friction force? How can you tell?
 - Is the object at rest, moving at a constant velocity, or speeding up? Explain.
- a.** The F_f arrow is half as long as the F_{app} arrow, so **$F_f \approx 30 \text{ N}$** . Arrow length shows the size of a force.
- b. Speeding up to the right.** The horizontal forces do not balance (the longer arrow points right), so the object accelerates in that direction. The vertical forces balance.

Part B: Drawing Free-Body Diagrams

Draw a free-body diagram for each object. Label every arrow and make the lengths match the sizes of the forces.

3. Luis pushes on a heavy 150 N box with a 40 N horizontal force, but the box does not move.

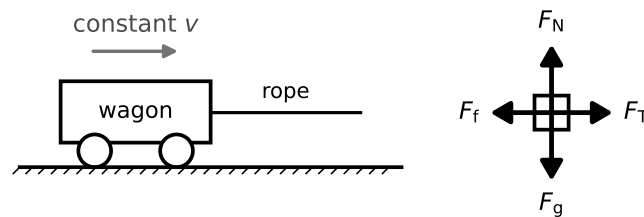


The box is at rest, so the forces balance in both directions.

Vertical: $F_N = F_g = 150 \text{ N}$ (equal arrows up and down).

Horizontal: friction from the floor balances the push: $F_f = F_{\text{app}} = 40 \text{ N}$ (equal arrows left and right).

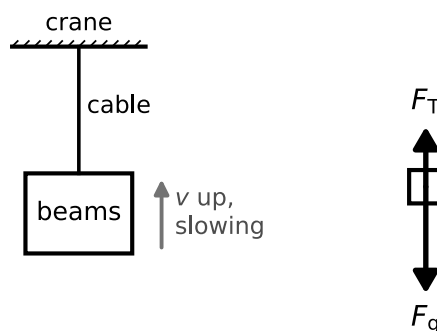
4. A wagon is pulled to the right across a sidewalk with a horizontal rope. It moves at a constant velocity.



Things touching the wagon: the rope (tension, right) and the sidewalk (normal force up and friction left). Then add gravity (down).

Constant velocity means the forces balance: $F_T = F_f$ and $F_N = F_g$, so opposite arrows are the same length.

5. A crane cable lifts a bundle of steel beams. The beams are moving up but slowing down as they near the top.



Only the cable touches the beams, so there is tension (F_T) up. Gravity (F_g) points down.

The beams are slowing down while moving up, so the unbalanced force points **down**: $F_g > F_T$. Draw the F_g arrow longer.

Moving up does not require an upward unbalanced force. The beams keep rising because of inertia.

-
6. An acorn falls from a tall oak tree. Air resistance acts on it, but the acorn is still speeding up.



Nothing solid touches the acorn. The air pushes up on it (F_{air} , opposite its motion), and gravity (F_g) pulls down.

It is speeding up as it falls, so the forces are unbalanced downward: $F_g > F_{\text{air}}$. Draw the F_g arrow longer.