

Part A: Force, Mass, and Acceleration

1. Marcus gives an empty 8 kg shopping cart and a full 32 kg shopping cart the same net push. How does the full cart's acceleration compare to the empty cart's? Explain using Newton's second law.
 The full cart has 4 times the mass ($32 \text{ kg} / 8 \text{ kg} = 4$). Acceleration is inversely proportional to mass, $a = F_{\text{net}}/m$, so the full cart's acceleration is **one fourth** of the empty cart's.

2. A net force gives a toy car an acceleration of 3.0 m/s^2 . Predict the new acceleration in each case.
 - a. The net force is doubled and the mass stays the same.
 - b. The mass is tripled and the net force stays the same.
 - c. Both the net force and the mass are doubled.
 - a. a is directly proportional to F_{net} : $2 \times 3.0 = \mathbf{6.0 \text{ m/s}^2}$
 - b. a is inversely proportional to m : $3.0 / 3 = \mathbf{1.0 \text{ m/s}^2}$
 - c. The two changes cancel: $(2/2) \times 3.0 = \mathbf{3.0 \text{ m/s}^2}$

Part B: Using $F_{\text{net}} = ma$

Show Knowns, Equation, Substitute, and Answer with units for each problem.

3. A soccer player kicks a 0.45 kg ball. During the kick, the net force on the ball is 27 N forward. What is the ball's acceleration?
Knowns: $F_{\text{net}} = 27 \text{ N forward}$, $m = 0.45 \text{ kg}$
Equation: $a = F_{\text{net}}/m$
Substitute: $a = 27 \text{ N} / 0.45 \text{ kg} = 27 \text{ kg}\cdot\text{m/s}^2 / 0.45 \text{ kg}$
Answer: $a = \mathbf{60. \text{ m/s}^2 \text{ forward}}$ ($6.0 \times 10^1 \text{ m/s}^2$)

4. A 1,350 kg car speeds up from a stoplight with an acceleration of 2.40 m/s^2 east. What net force acts on the car?
Knowns: $m = 1,350 \text{ kg}$, $a = 2.40 \text{ m/s}^2 \text{ east}$
Equation: $F_{\text{net}} = ma$
Substitute: $F_{\text{net}} = (1,350 \text{ kg})(2.40 \text{ m/s}^2) = 3,240 \text{ kg}\cdot\text{m/s}^2$
Answer: $F_{\text{net}} = \mathbf{3,240 \text{ N east}}$

5. A net force of 84 N gives a loaded wheelbarrow an acceleration of 3.5 m/s^2 . What is the mass of the loaded wheelbarrow?

Knowns: $F_{\text{net}} = 84 \text{ N}$, $a = 3.5 \text{ m/s}^2$

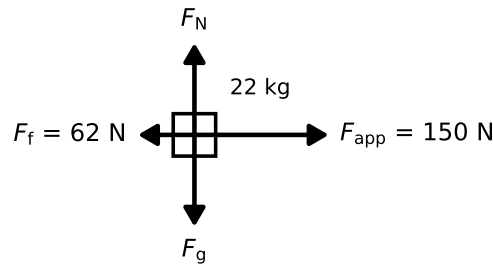
Equation: $F_{\text{net}} = ma$, so $m = F_{\text{net}}/a$

Substitute: $m = 84 \text{ N} / 3.5 \text{ m/s}^2 = 84 \text{ kg} \cdot \text{m/s}^2 / 3.5 \text{ m/s}^2$

Answer: $m = 24 \text{ kg}$

Part C: Net Force First

6. The free-body diagram shows the forces on a 22 kg crate being pushed across a warehouse floor. The vertical forces are balanced.



- Find the net force on the crate.
- Find the crate's acceleration.
- Kenji uses only the 150 N push and gets the wrong answer. What acceleration does Kenji get, and why is it wrong?

a. East (right) is +: $F_{\text{net}} = F_{\text{app}} - F_f = 150 \text{ N} - 62 \text{ N} = \mathbf{88 \text{ N east}}$

b. $a = F_{\text{net}}/m = 88 \text{ N} / 22 \text{ kg} = \mathbf{4.0 \text{ m/s}^2 \text{ east}}$

c. Kenji gets $150 \text{ N} / 22 \text{ kg} = \mathbf{6.8 \text{ m/s}^2}$. It is wrong because Newton's second law uses the **net** force, and friction cancels part of the push.

7. In a lab, Aaliyah pulls a cart with a force sensor and measures its acceleration. Friction is small enough to ignore, so the pull is the net force. Her data are shown.

Net force (N)	Acceleration (m/s^2)
0.50	1.0
1.00	2.0
1.50	3.0
2.00	4.0

- How are net force and acceleration related? How can you tell from the data?
- Use one row of data to find the mass of the cart. Then predict its acceleration for a 2.60 N net force.

a. Directly proportional. When the force doubles (0.50 N to 1.00 N), the acceleration doubles (1.0 to 2.0 m/s^2). A graph of a vs. F_{net} is a straight line through the origin.

b. $m = F_{\text{net}}/a = 1.00 \text{ N} / 2.0 \text{ m/s}^2 = \mathbf{0.50 \text{ kg}}$ (every row gives the same mass). Prediction: $a = F_{\text{net}}/m = 2.60 \text{ N} / 0.50 \text{ kg} = \mathbf{5.2 \text{ m/s}^2}$