PHYS11 CH:4 The Three Laws That Run the Universe

From Newton to You

Mr. Gullo

December 2025

Outline

The Mystery

Why does a dolphin jump the way it does?

What invisible rules guide its motion?

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Three simple laws explain ALL motion in the universe.

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Three simple laws explain ALL motion in the universe.

From dolphins to rockets to you.

Dolphin in Motion

Dolphin in Motion

The Mental Model

The dolphin's path is not random. Physics predicts every curve, every arc.

Learning Objectives

By the end of this lesson, you will be able to:

- **4.1:** Differentiate between force, net force, and dynamics

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By the end of this lesson, you will be able to:

- **4.1:** Differentiate between force, net force, and dynamics
- **4.1:** Draw a free-body diagram

4.1 The Source Code of Motion

Nature's Operating System

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Forces have:

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The Mental Model

Force is like an invisible hand pushing or pulling objects.

4.1 Combining Forces

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Key Point

Opposite forces can cancel each other out!

4.1 The Free-Body Diagram

A **free-body diagram** shows:

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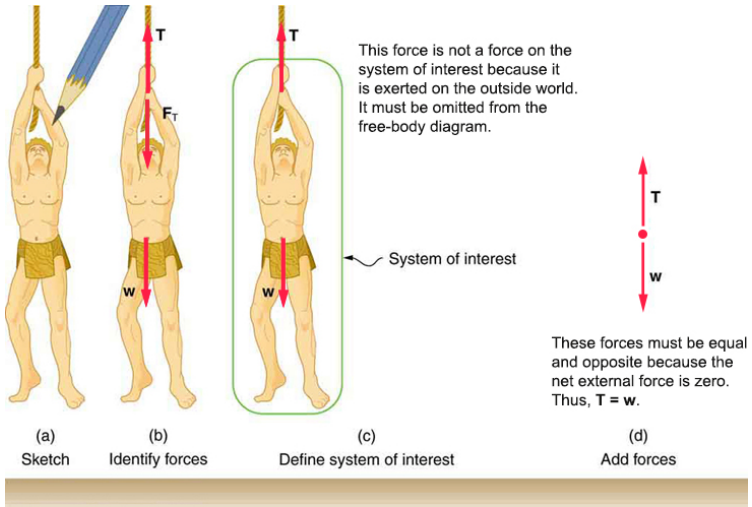

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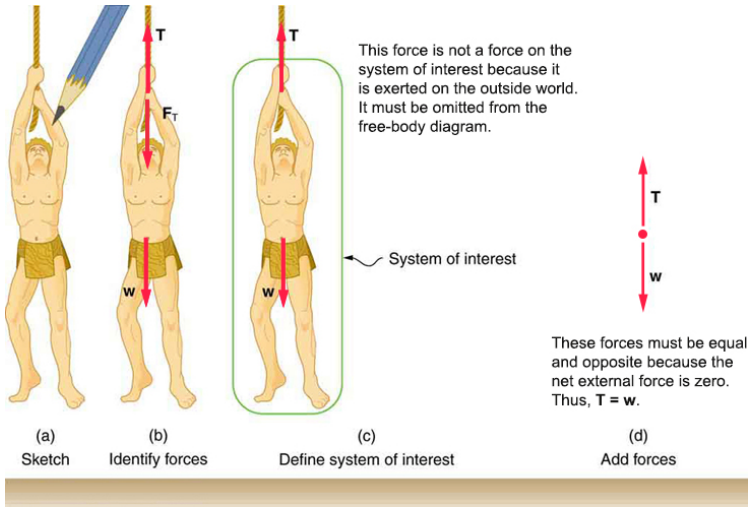
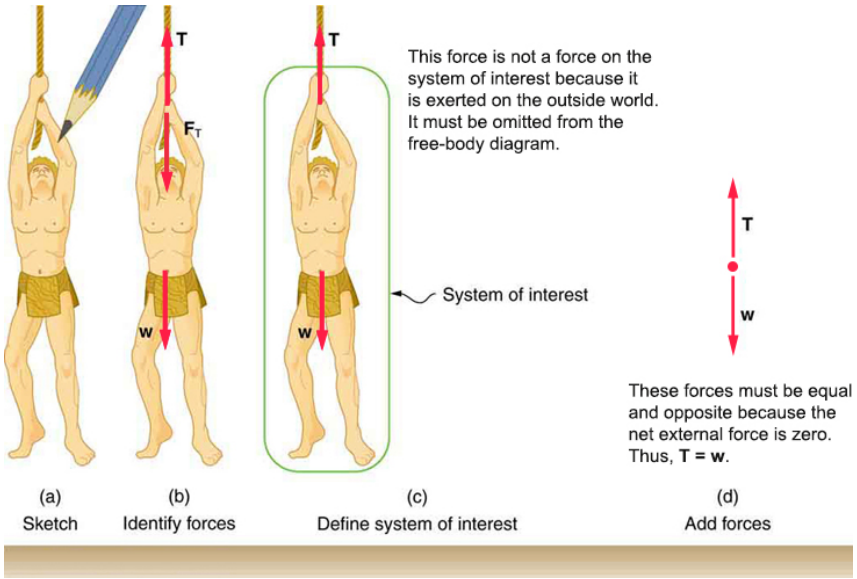


The Tool

Free-body diagrams are the first step to solving ANY force problem.

4.1 Balanced Forces



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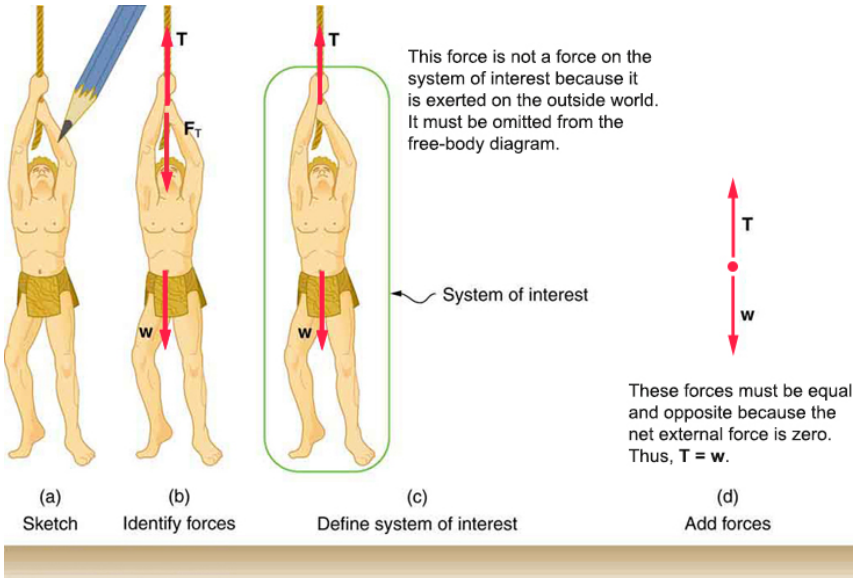

Tension force (up) = Weight force (down)

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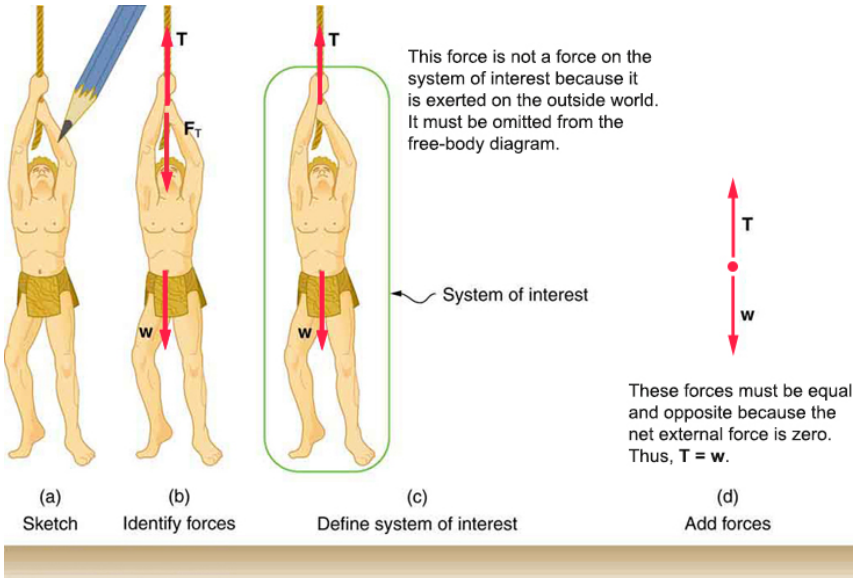

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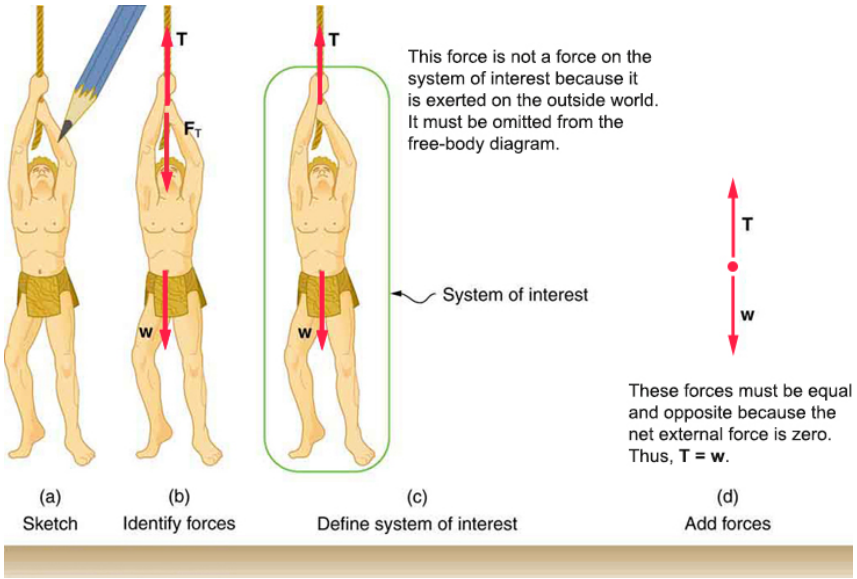

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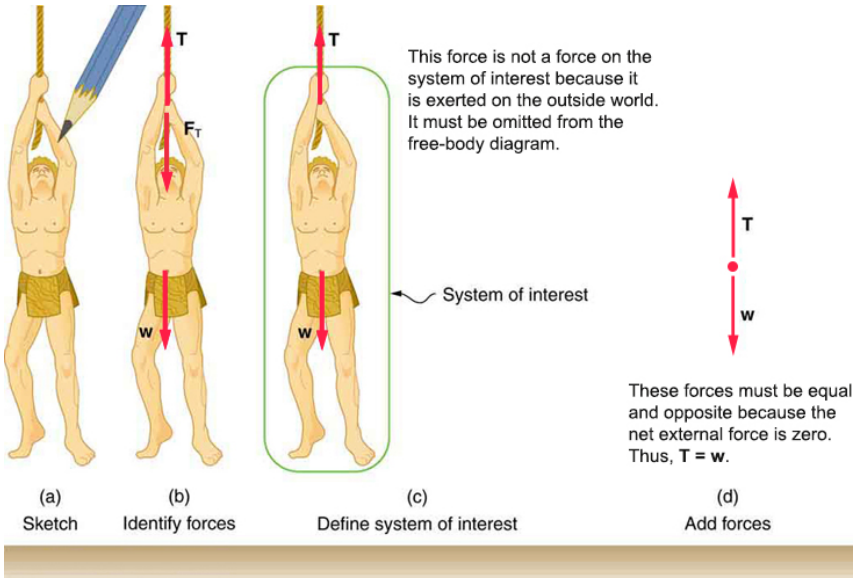

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Object hangs motionless.

Learning Objectives

By the end of this section, you will be able to:

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- **4.2:** Describe Newton's first law and friction
- **4.2:** Discuss the relationship between mass and inertia

The Law of Laziness

Objects don't like to change what they're doing.

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Universal Law I: Newton's First Law

1. A body at rest stays at rest
2. A body in motion stays in motion at constant velocity

...unless acted on by a net external force.

The Intuition Trap

What Your Brain Gets Wrong

Your brain says: Moving objects naturally slow down and stop.

Reality: A hidden force is slowing them down.

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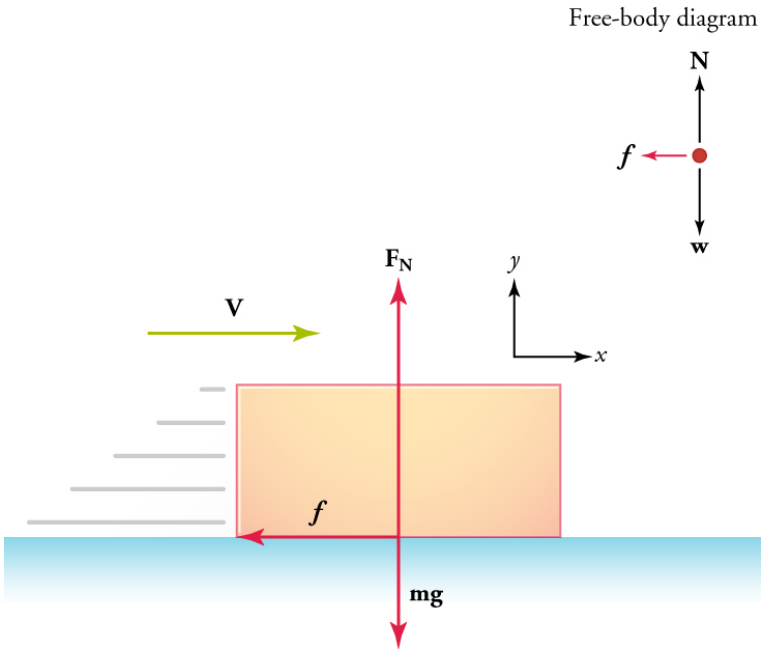
That hidden force is **friction**.

Without friction, objects would glide forever at constant velocity.

4.2 Friction: The Hidden Resistance



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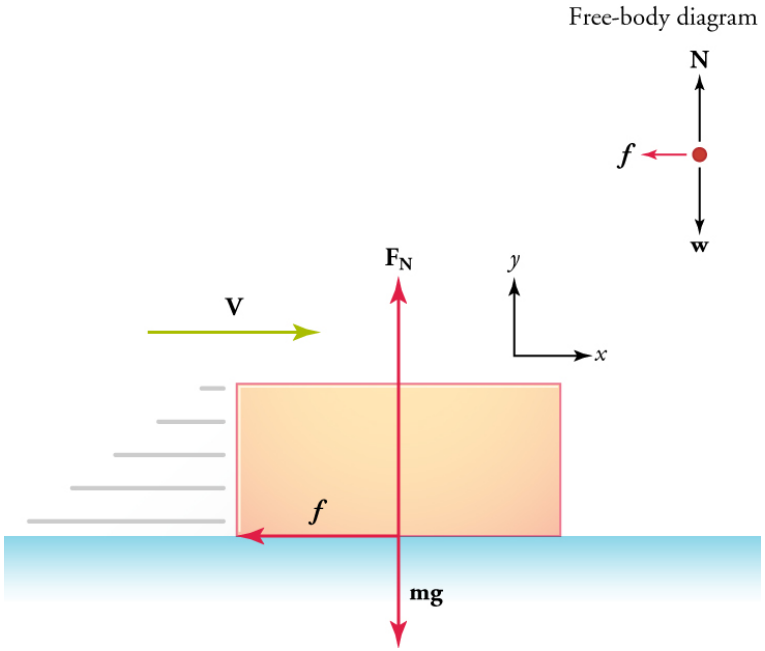

Friction acts opposite to the direction of motion.

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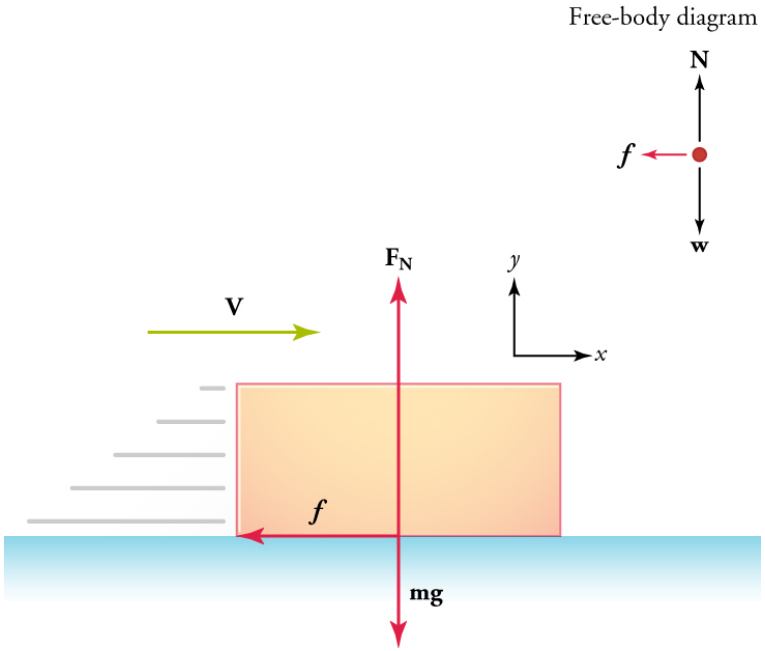

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It's why things slow down on their own (seemingly).

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Why? Newton's first law says constant velocity means net force = 0.
+50 N + (-50 N) = 0

4.2 Inertia: The Resistance to Change

The Universal Law

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In the Real World

Changing the motion of a truck is harder than changing the motion of a skateboard.

Mass is the measure of inertia.

4.2 Mass vs Weight

Civilian View vs. Reality

Civilian: Mass and weight are the same thing.

Physicist: Mass is matter. Weight is gravitational force.

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Civilian: Mass and weight are the same thing.

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Mass: Amount of matter (same on Earth and Moon)

Weight: Gravitational force (changes on Moon)

Learning Objectives

By the end of this section, you will be able to:

- **4.3:** Describe Newton's second law, both verbally and mathematically

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The Universal Pushback

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Universal Law II: Newton's Second Law

$$\boxed{\vec{F}_{\text{net}} = m\vec{a}}$$

Net force equals mass times acceleration.

4.3 Reading the Equation

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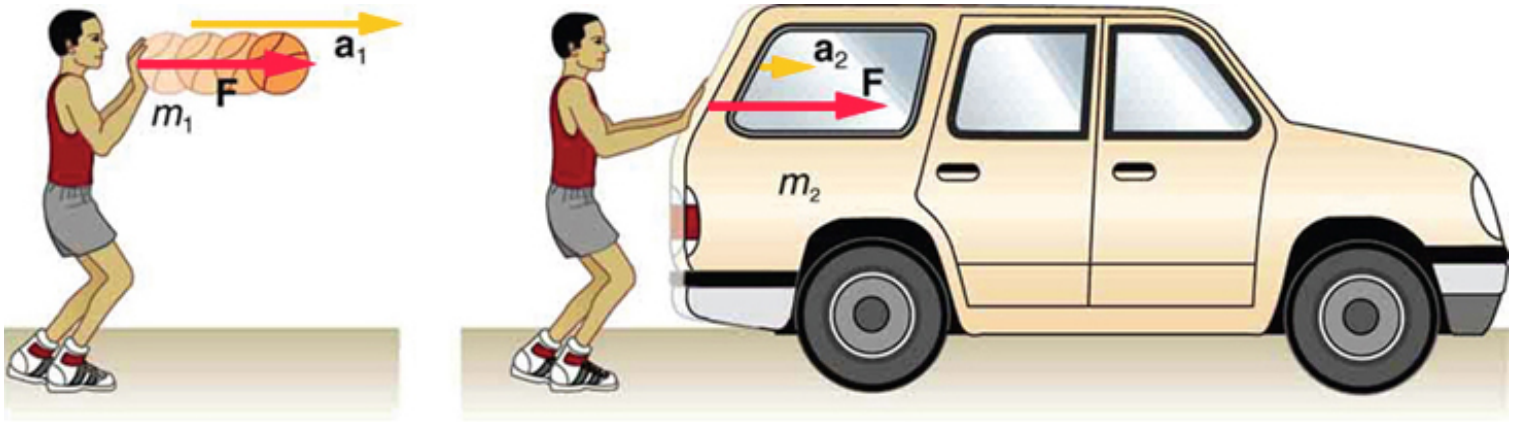
Key Insight

Same force on different masses produces different accelerations!

4.3 Same Force, Different Results



(a) (b)

The free-body diagrams for both objects are the same.

(c)

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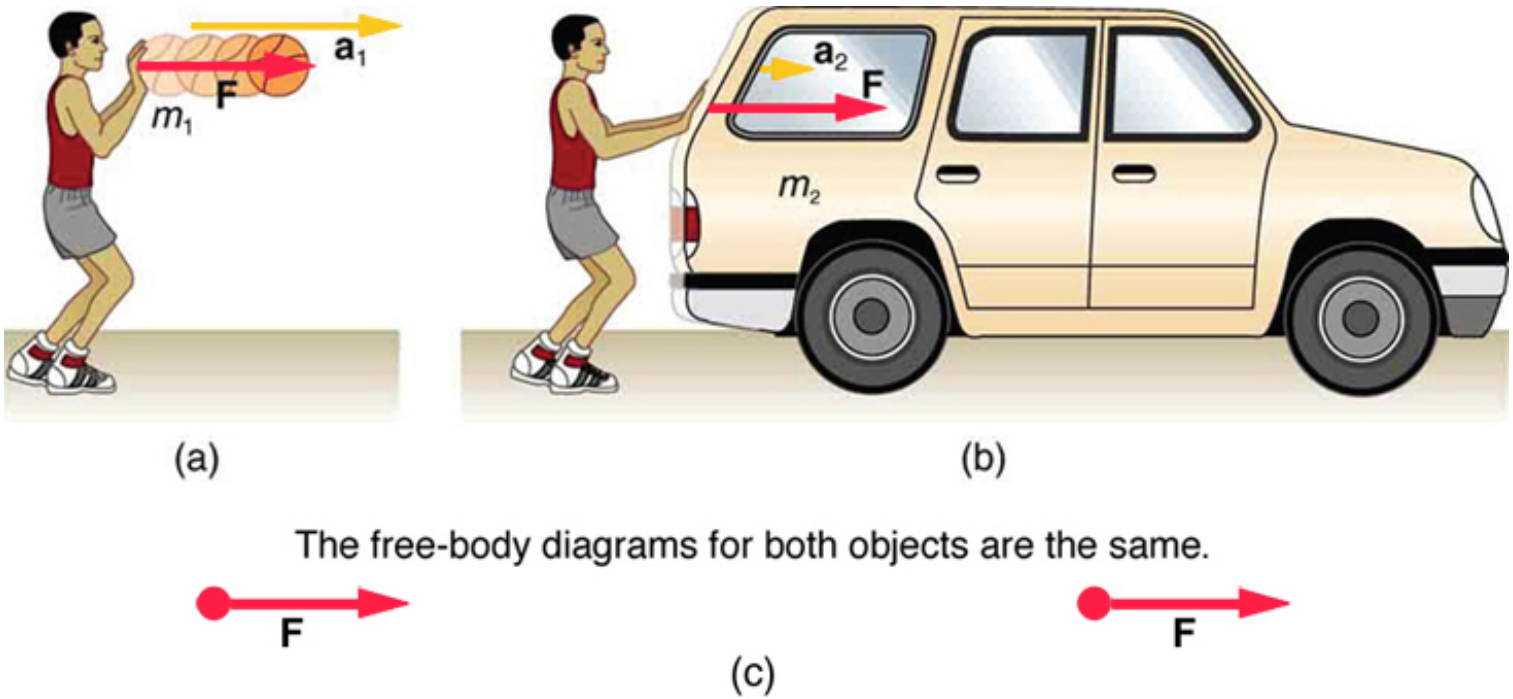

Same force, different masses, different accelerations.

4.3 The Newton

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In the US: $1\ \text{N} = 0.225\ \text{lb}$

4.3 Weight: A Special Force

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The Universal Law

$$\boxed{W = mg}$$

Weight equals mass times gravitational acceleration.

4.3 Weight Changes, Mass Doesn't

On Earth: $g = 9.8\ \text{m/s}^2$

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Example: 1.0-kg mass

- Earth: $W = (1.0)(9.8) = 9.8\ \text{N}$

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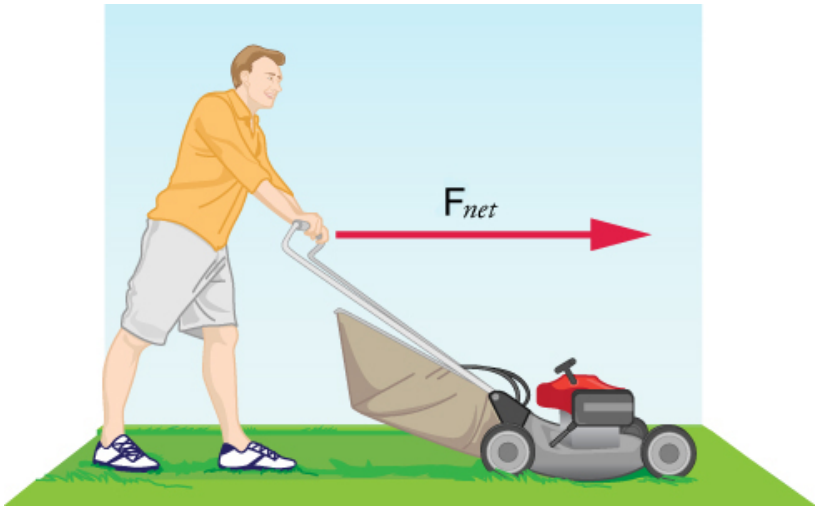
Same mass, different weight!

Attempt: Decoding Lawn Mower Motion



The Challenge

Net external force: 51 N

Mass: 24 kg

Find: Acceleration a

3 min, silent - Can you predict its acceleration?

Compare: Lawn Mower Strategy

Turn and talk (2 min):

1. What equation did you start with?
2. How did you rearrange it to solve for acceleration?
3. What units should your answer have?

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Name wheel: One pair share your approach (not your answer).

Reveal: The Math of Acceleration

Self-correct in a different color:

E - Equation: $F_{\text{net}} = ma$

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$$\boxed{a = 2.1\ \text{m/s}^2}$$

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$$\boxed{a = 2.1\ \text{m/s}^2}$$

Check: Speed increases by 2.1 m/s every second. Reasonable for a person pushing!

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The Great Exchange

Why does punching a wall hurt *your* hand?

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The Mental Model

You cannot touch something without being touched back.

Universal Law III: Newton's Third Law

The Law of Action and Reaction

$$\boxed{\vec{F}_{A\to B} = -\vec{F}_{B\to A}}$$

When object A exerts a force on object B,
object B exerts an equal and opposite force on object A.

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Forces always come in **action-reaction pairs**.

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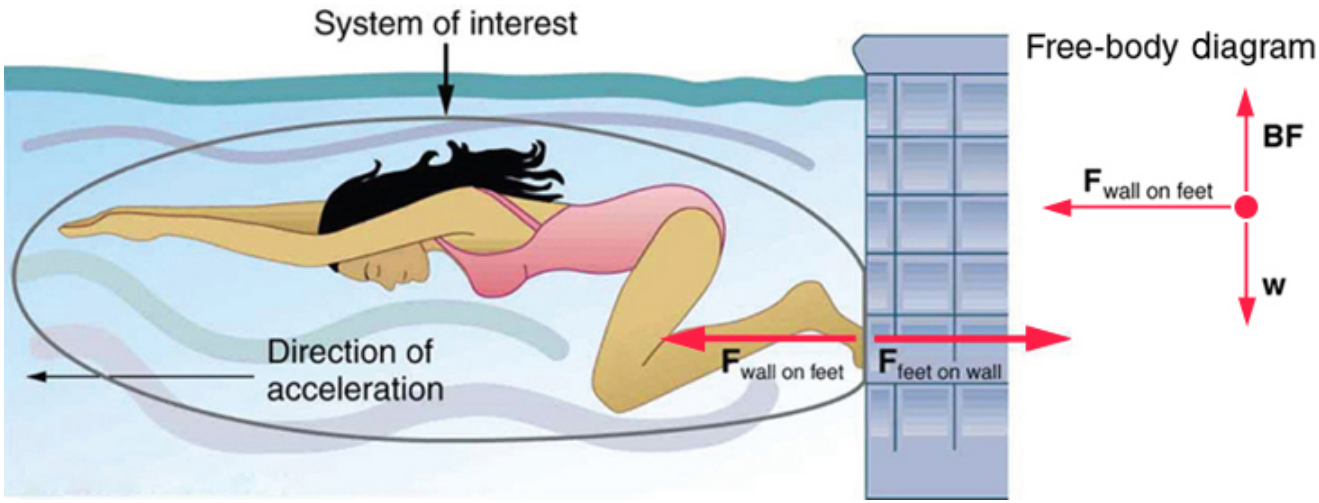
Equal magnitude, opposite direction.

4.4 Swimmer Pushing Off Wall



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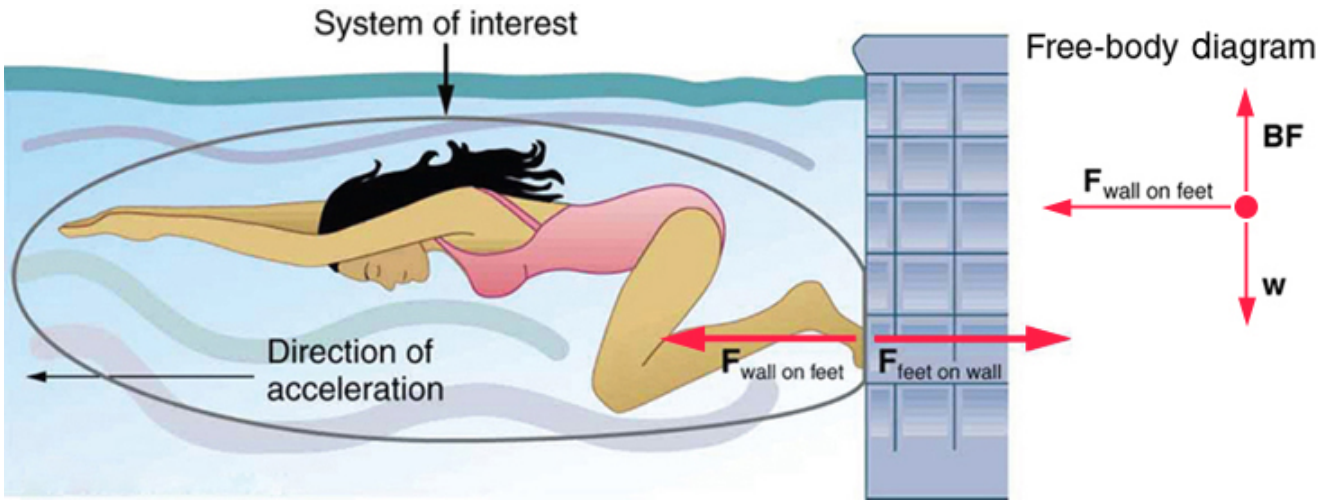

Swimmer pushes wall backward $\rightarrow$ Wall pushes swimmer forward

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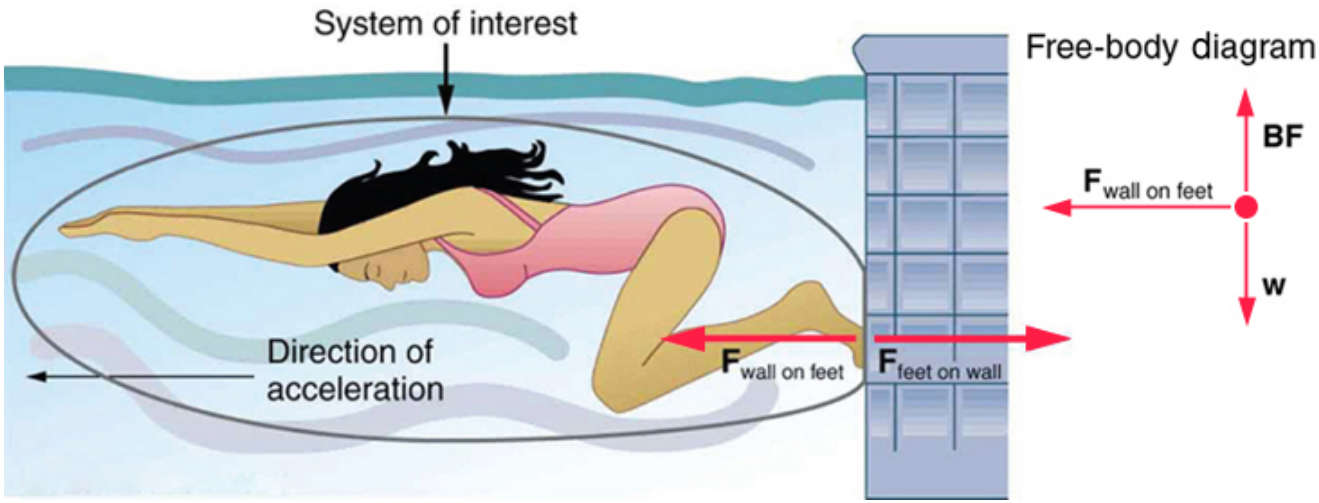

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The Paradox

Civilian View vs. Reality

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Bug has tiny mass $\rightarrow$ huge acceleration $\rightarrow$ splat

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Truck has huge mass $\rightarrow$ tiny acceleration $\rightarrow$ barely notices

4.4 The Normal Force

When an object rests on a surface:

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When an object rests on a surface:

Weight pulls down

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Normal force pushes up (perpendicular to surface)

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For horizontal surface

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Equal magnitude, opposite direction $\rightarrow$ net force $= 0$

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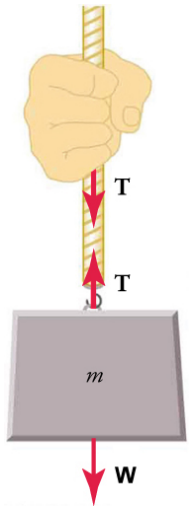

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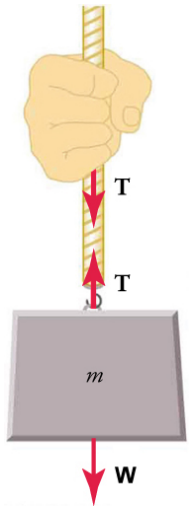

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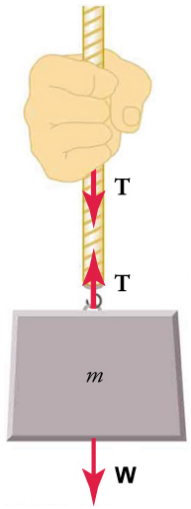

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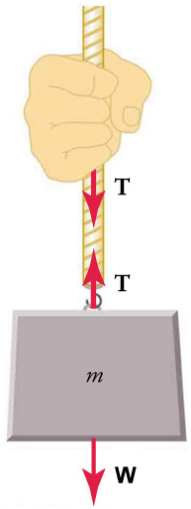

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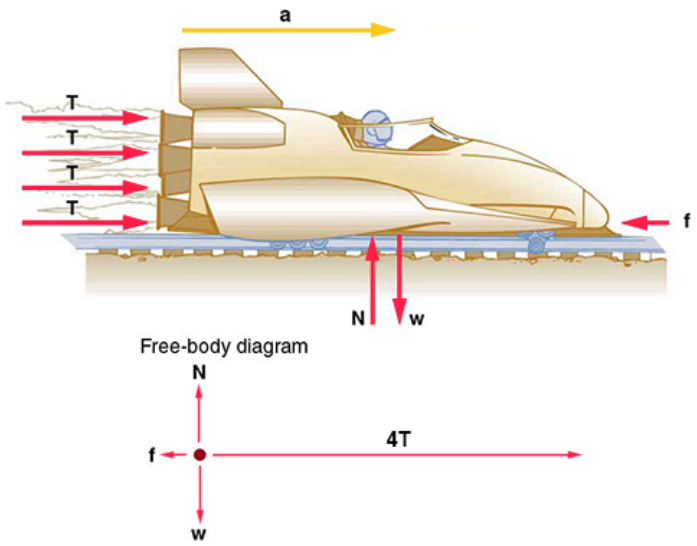
Rope pulls up on mass, mass pulls down on rope.

4.4 Thrust: The Rocket Force



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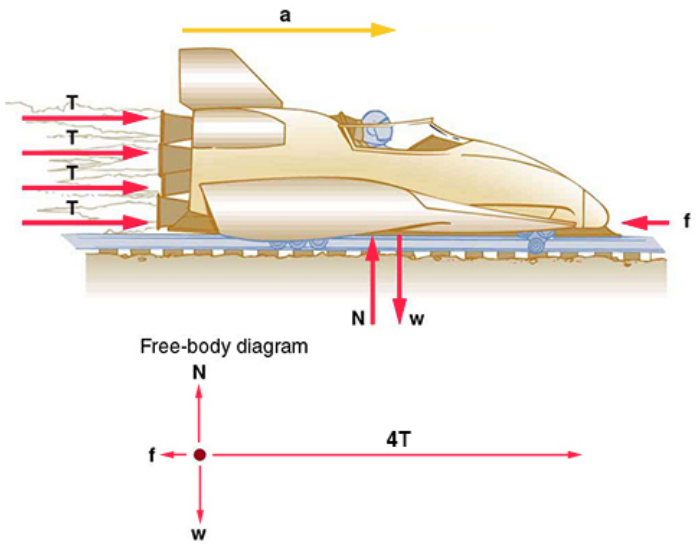

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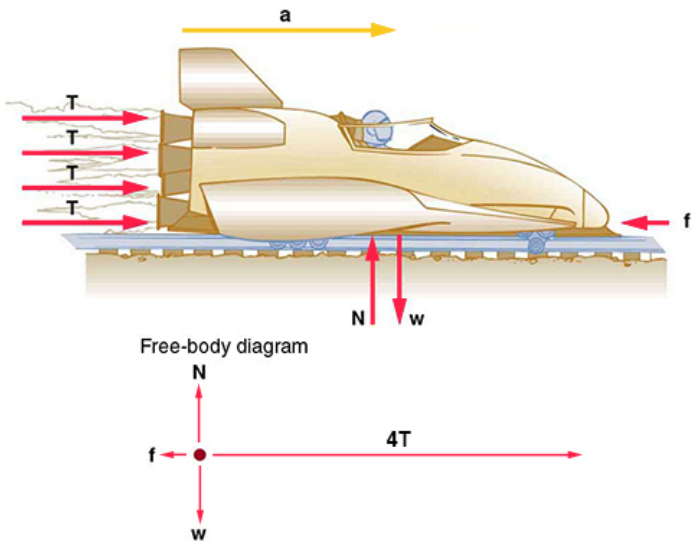

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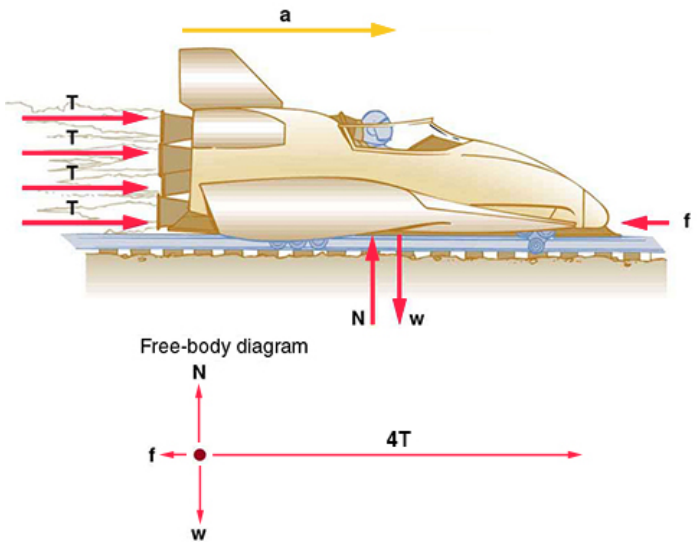

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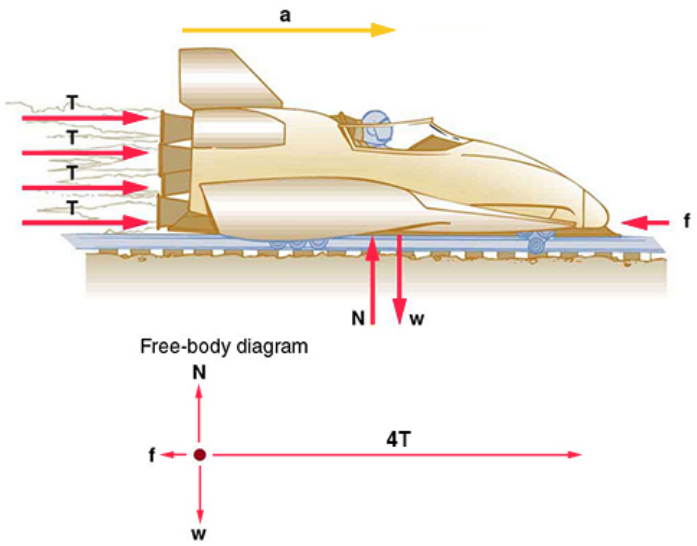

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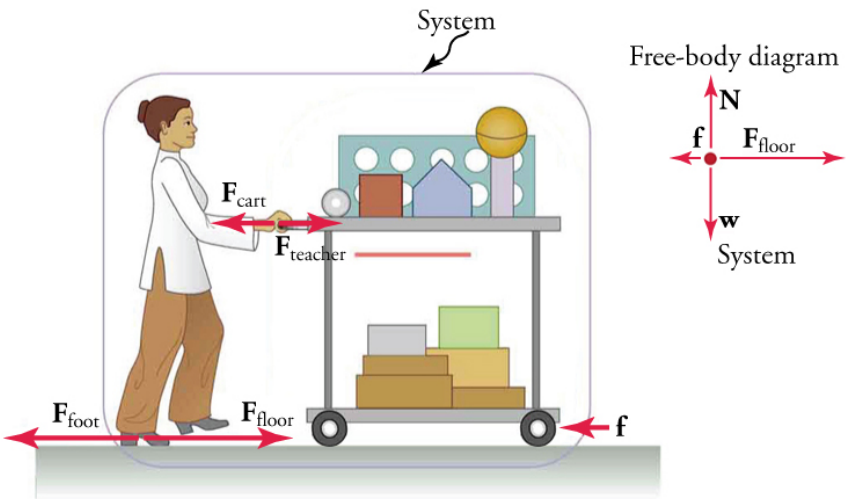
Misconception

Rockets don't push on the ground or air.
They push on the gas they expel!

Attempt: Equipment Cart



The Challenge

Foot applies 150 N backward

Friction: 24.0 N

Mass: 84.0 kg total

Find: Acceleration *a*

3 min, silent - Can you decode this system?

Compare: Cart Strategy

Turn and talk (2 min):

1. What forces act on the system?
2. How did you find net force?
3. What equation did you use to find acceleration?

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Name wheel: One pair share your approach (not your answer).

Reveal: The Math of Systems

Self-correct in a different color:

Step 1: Find net force

$$F_{\text{net}} = F_{\text{floor}} - f = 150 - 24.0 = 126 \text{ N}$$

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$$a = \frac{F_{\text{net}}}{m} = \frac{126}{84.0} = \boxed{1.5 \text{ m/s}^2}$$

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Check: Speed increases by 1.5 m/s every second. Reasonable!

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The Three Laws That Run Reality

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These three laws explain ALL motion in the universe.

Key Equations

$$\text{Newton's Second Law:} \quad \vec{F}_{\text{net}} = m\vec{a} \tag{1}$$

$$\text{Weight:} \quad W = mg \tag{2}$$

$$\text{Friction:} \quad f = \mu N \tag{3}$$

$$\text{Normal Force (horizontal):} \quad N = mg \tag{4}$$

Homework

Complete the assigned problems

posted on the LMS