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:

- The object as a single point

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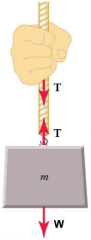

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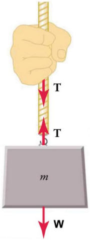
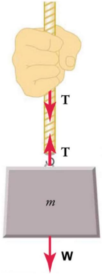


The Tool

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

4.1 Balanced Forces



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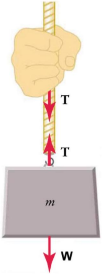

Tension force (up) = Weight force (down)

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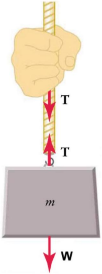

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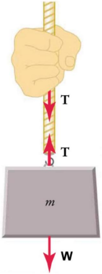

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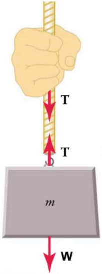

Tension force (up) = Weight force (down)

Equal magnitude, opposite directions

Net force = ZERO

Object hangs motionless.

Learning Objectives

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

- **4.2:** Describe Newton's first law and friction

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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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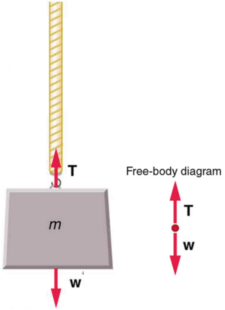
That hidden force is **friction**.

Without friction, objects would glide forever at constant velocity.

4.2 Friction: The Hidden Resistance



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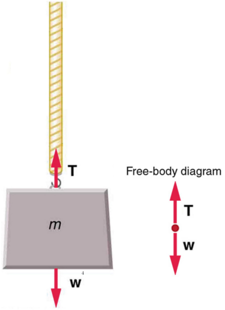

Friction acts opposite to the direction of motion.

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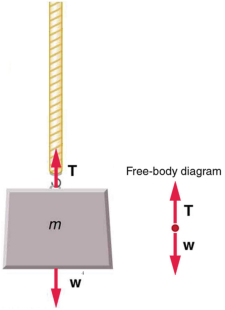

Friction acts opposite to the direction of motion.

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 $= 0$.

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The box moves at **constant velocity**.

What is the force of friction?

The Answer

Friction $=$ -50 N

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

Inertia is the tendency to maintain your state of motion.

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

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Greater mass = greater inertia

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

Weight: Gravitational force (changes on Moon)

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- **4.3:** Use Newton's second law to solve problems

What happens when net force is NOT zero?

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The object **accelerates**.

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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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Acceleration is directly proportional to force:
Double the force $\rightarrow$ double the acceleration

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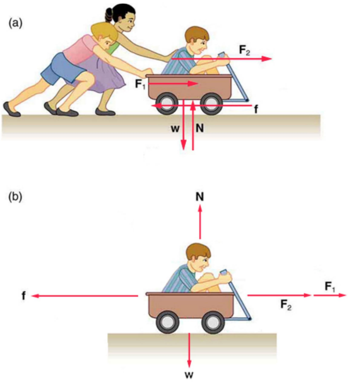
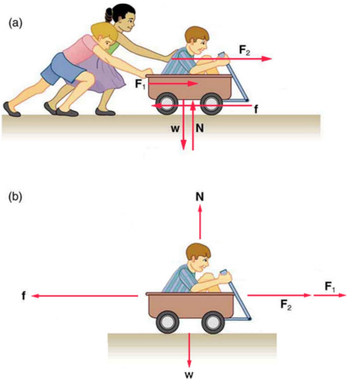
Key Insight

Same force on different masses produces different accelerations!

4.3 Same Force, Different Results





Same force, different masses, different accelerations.

4.3 The Newton

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A 1-kg mass accelerated at 1 $\mathrm{m/s^2}$ requires 1 N of force.

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

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 (3 min, silent)

Net external force on a lawn mower is 51 N parallel to the ground. Mass of mower is 24 kg.

Given:

- $F_{\text{net}} = 51$ N
- $m = 24$ kg

Find: Acceleration a

Can you predict its acceleration? Work silently.

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?
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Self-correct in a different color:

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

Reveal: The Math of Acceleration

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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?

Why does punching a wall hurt *your* hand?

The wall punched you back.

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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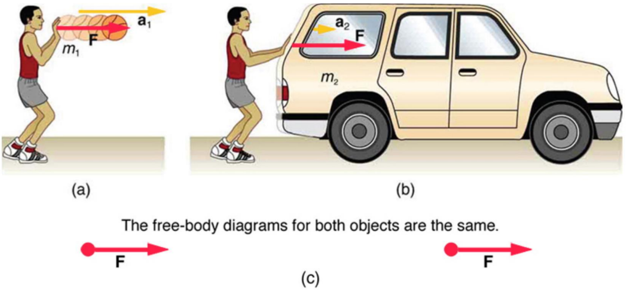
Equal magnitude, opposite direction.

4.4 Swimmer Pushing Off Wall



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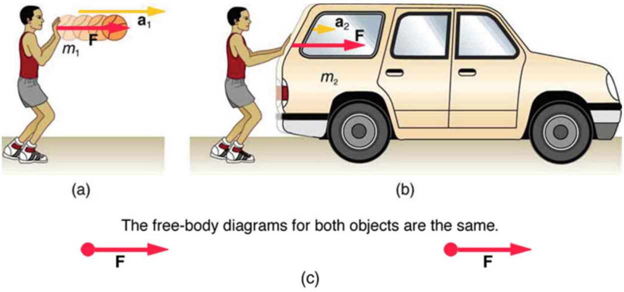
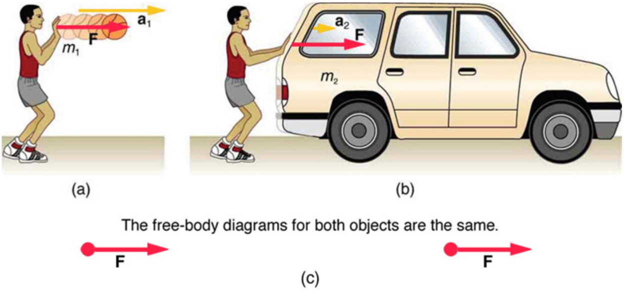


Swimmer pushes wall backward → Wall pushes swimmer forward



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The Paradox

Civilian View vs. Reality

Civilian: "The truck hits the bug harder than the bug hits the truck."

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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:

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Normal force pushes up (perpendicular to surface)

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For horizontal surface

$$N = mg$$

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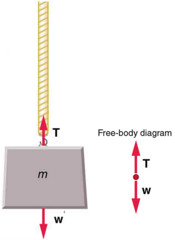
Equal magnitude, opposite direction $\rightarrow$ net force $= 0$

4.4 Tension in a Rope



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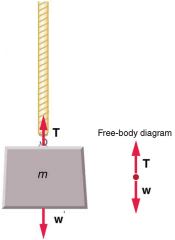

Tension is the pulling force along a connector (rope, string, cable).

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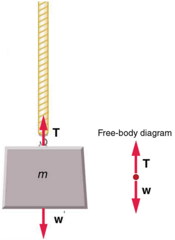

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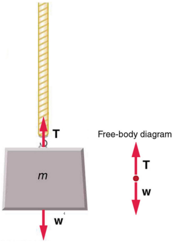

Tension is the pulling force along a connector (rope, string, cable).

For a stationary mass: $T = W = mg$

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

4.4 Thrust: The Rocket Force

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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 (3 min, silent)

A teacher pushes a cart. Her foot applies 150 N backward on the floor. Friction opposing motion is 24.0 N.

Given:

- $F_{\text{floor}} = 150$ N (Newton's 3rd law)
- $f = 24.0$ N (friction)
- Total mass: $m = 65.0 + 12.0 + 7.0 = 84.0$ kg

Find: Acceleration a

Can you decode this system? Work silently.

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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Self-correct in a different color:

Step 1: Find net force

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

Reveal: The Math of Systems

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

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$$m = 65.0 + 12.0 + 7.0 = 84.0 \text{ kg}$$

Step 3: Calculate acceleration

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

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

What You Now Know

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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