

# PHYS11 CH:1 The Rules That Run the Universe

## From Atoms to Galaxies

Mr. Gullo

December 2025

# Outline

- 1 Introduction
- 2 Physics: Definitions and Applications
- 3 The Scientific Methods
- 4 Physical Quantities and Units
- 5 Summary

What if one set of rules explained  
*everything in the universe?*

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From the atoms in your fingertips to galaxies 2.5 million light years away...

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From the atoms in your fingertips to galaxies 2.5 million light years away...

The same laws apply.

# 2.5 Million Light Years Away



## 2.5 Million Light Years Away



### The Mental Model

The force holding you in your seat is the same force arranging billions of stars in Andromeda.

# Learning Objectives

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- **1.1:** Describe the definition, aims, and branches of physics



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- **1.1:** Describe the definition, aims, and branches of physics
- **1.1:** Distinguish classical physics from modern physics
- **1.1:** Describe how physics is used in other sciences and everyday technology

# 1.1 The Source Code of Reality

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## The Mental Model

Physics is like discovering the source code that runs reality.

# 1.1 Physics in Your Phone





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## Real-World: Smartphone Physics

- Electric circuits and current flow
- GPS: relationship between speed, distance, time
- Screen: optics and light

# 1.1 Ancient Physics: Stonehenge



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Built 3000-1000 BC as an astronomical observatory.

# 1.1 Branches of Physics

## Classical Physics

- Mechanics (motion)
- Thermodynamics (heat)
- Electricity and Magnetism
- Optics (light)
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## Modern Physics

- Relativity
- Quantum Mechanics
- Nuclear Physics
- Particle Physics

# 1.1 The Intuition Trap

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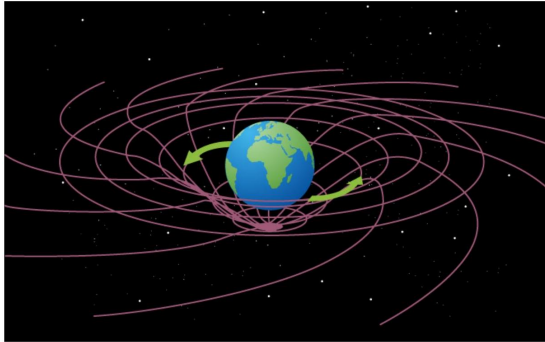
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## What Your Brain Gets Wrong

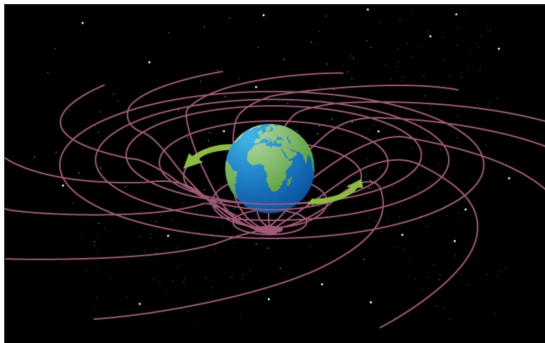
Your intuition evolved for everyday speeds and sizes.

At extremes (tiny, fast, massive), **intuition fails completely.**

# 1.1 Relativity: Time and Space



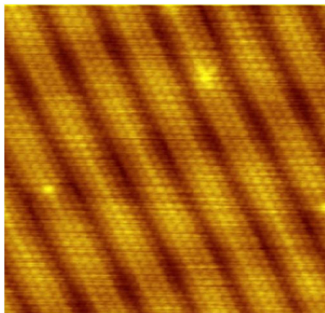
# 1.1 Relativity: Time and Space



## Einstein's discoveries:

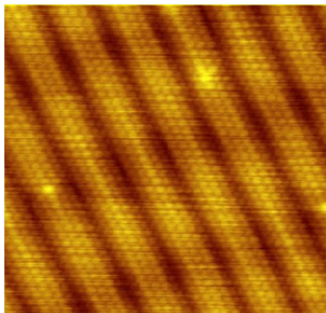
- Time slows down at high speeds
- Length contracts at high speeds
- Gravity warps space-time

# 1.1 Quantum Mechanics



Individual atoms visible with scanning tunneling microscope

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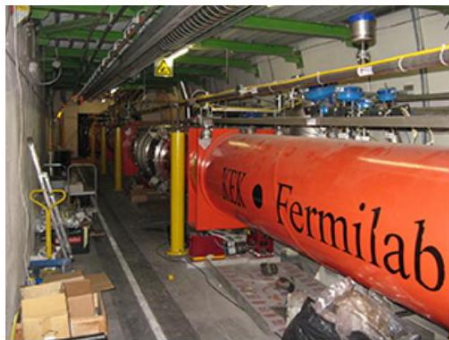


Individual atoms visible with scanning tunneling microscope

## Studies:

- Atoms and subatomic particles
- Behavior at tiny scales
- Particles moving near light speed

# 1.1 Particle Colliders



Fermilab particle accelerator

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Fermilab particle accelerator

Accelerate particles to near light speed to study their properties.

# 1.1 Microwaves and Metal





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Microwaves increase electron movement in metal → electrical current → sparks!

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## Warning

Never put metal in a microwave - fire hazard!

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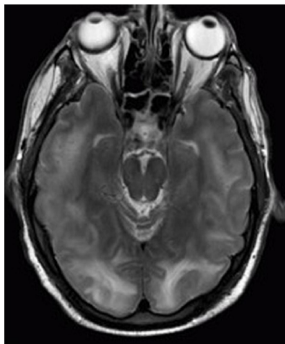
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- **Engineering:** structural design, acoustics
- **Architecture:** stability, heating, lighting

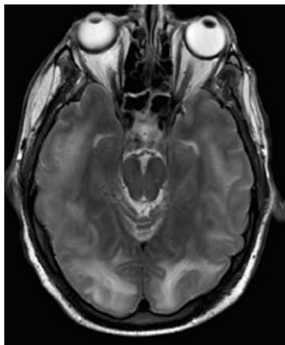


# 1.1 Medical Applications

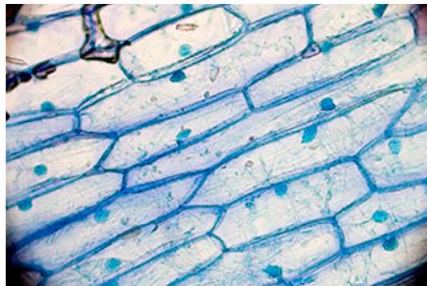


MRI scan

# 1.1 Medical Applications



MRI scan



Cell walls

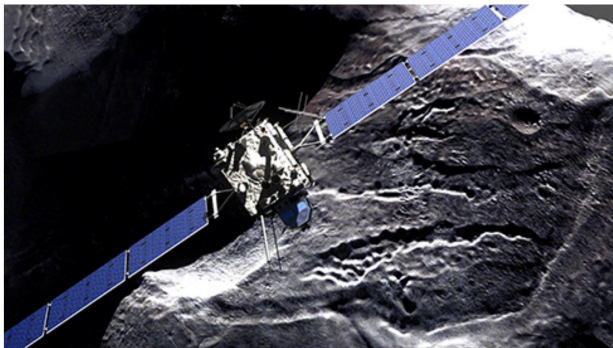
MRI uses electromagnetic waves. Cell walls use physics of selective permeability.

# 1.1 Rosetta Mission



Rosetta spacecraft with Philae lander

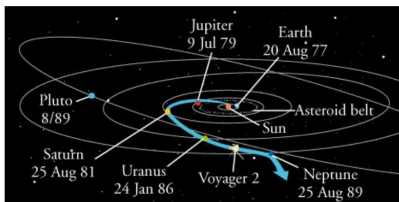
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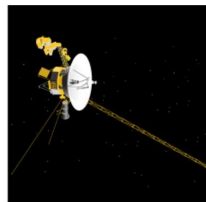
Rosetta spacecraft with Philae lander

**Achievement (2014):** First spacecraft to orbit and land on a comet.

# 1.1 Voyager Missions



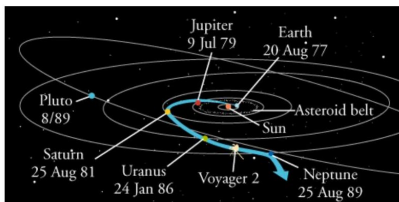
(a)



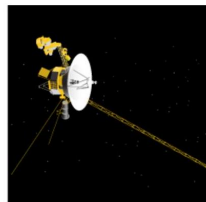
(b)

Voyager trajectory using planetary gravity

# 1.1 Voyager Missions



(a)



(b)

Voyager trajectory using planetary gravity

**Voyager 1:** Launched 1977, now in interstellar space!

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- **1.2:** Explain how the methods of science are used to make discoveries
- **1.2:** Define a scientific model and describe examples
- **1.2:** Compare and contrast hypothesis, theory, and law

## 1.2 The Scientific Method

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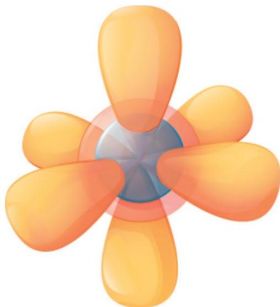
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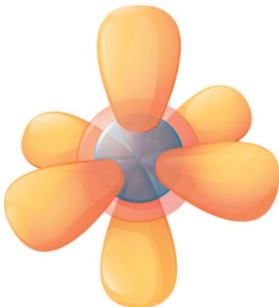
- Physical models (3D atom model)
- Mathematical equations
- Computer simulations
- Diagrams and visualizations

## 1.2 Electron Cloud Model



Electron probability clouds around atom nucleus

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Electron probability clouds around atom nucleus

**Shows:** Where electrons are likely to be found

**Limitation:** Cannot show exact position at any moment

## 1.2 The Vocabulary of Discovery

### The Ladder of Certainty

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### Civilian View vs. Reality

**Civilian:** "It's just a theory" = probably wrong

**Physicist:** "Theory" = extensively tested and supported

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### Universal Law: The Pushback

$$F = ma$$

Force equals mass times acceleration. Works on Earth, Mars, and distant galaxies.

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Scientists say theories are **supported**, not **proven**.

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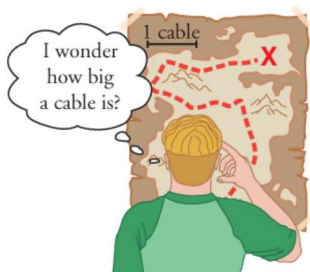
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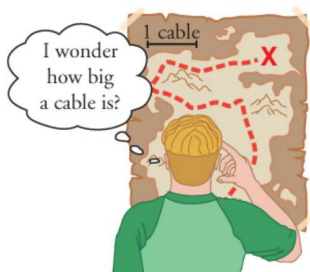
- **1.3:** Use SI units and perform conversions
- **1.3:** Apply significant figures in calculations
- **1.3:** Create and interpret graphs of physical relationships

## 1.3 Standard Units



Distance without units is meaningless!

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**Units are standardized values for measurement.**

Without them, we can't compare or communicate measurements.

# 1.3 SI Base Units

Quantity	SI Unit
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Electric current	ampere (A)
Temperature	kelvin (K)
Amount of substance	mole (mol)
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All other units are **derived** from these seven.

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- 1960: Wavelengths of krypton light
- 1983: Based on speed of light (current)

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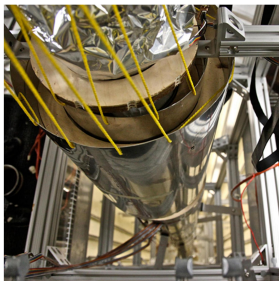
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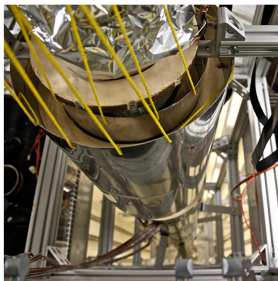
More stable and reproducible!

## 1.3 The Second



Atomic clock

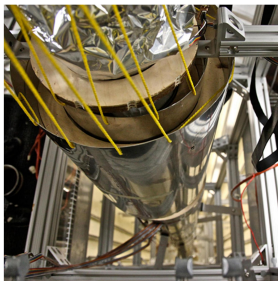
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Accurate to one microsecond per year!

# 1.3 Metric Prefixes

Prefix	Symbol	Power of 10	Example
giga-	G	$10^9$	gigameter
mega-	M	$10^6$	megawatt
kilo-	k	$10^3$	kilometer
(base)	-	$10^0$	meter
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Conversions are easy - just move decimal point!

## 1.3 Range of Measurements

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Physics spans 31 orders of magnitude!

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**Positive exponent:** Move decimal right (large number)

**Negative exponent:** Move decimal left (small number)

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**Ballpark estimate** for scale of a value.

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**Key:** Units cancel like algebra!

# Attempt: Decoding Motion

## The Challenge (3 min, silent)

A car travels 10.0 km in 20.0 min.

### Given:

- distance = 10.0 km
- time = 20.0 min

**Find:** Average speed in km/h

*Can you decode this motion? Work silently.*

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

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**Check:** 10 km in 1/3 hour = 30 km in 1 hour. Reasonable!

# 1.3 Accuracy vs Precision

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## Key Difference

Accuracy = correctness. Precision = consistency. You can have one without the other!

## 1.3 Target Analogy



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## 1.3 Significant Figures

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## Common Mistake

Leading zeros (0.0045) are NOT significant - they're just placeholders!

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Round to 2 sig figs: 4.5 m<sup>2</sup>

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**Notation:**  $11.0 \pm 0.2$  inches

Means: actual value between 10.8 and 11.2 inches



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The bag weighs  $5 \text{ lb} \pm 8\%$

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- 1 Physics = the source code of reality (atoms to galaxies)
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- 5 Sig figs = honesty about precision
- 6 Uncertainty = the humility of science

# Key Equations

$$\text{Average speed} = \frac{\text{distance}}{\text{time}} \quad (1)$$

$$\text{Percent uncertainty} = \frac{\delta A}{A} \times 100\% \quad (2)$$

Complete the assigned problems  
posted on the LMS