

## What is Physics?

**Unit:** Laboratory & Measurement

**NGSS Standards/MA Curriculum Frameworks (2016):** SP1, SP2, SP6, SP7

**AP® Physics 1 Learning Objectives/Essential Knowledge (2024):** SP3.B, SP3.C

**Mastery Objective(s):** (Students will be able to...)

- Explain what physics is and what is studied in different branches of physics.

**Success Criteria:**

- Explanation describes what is studied in each of the branches of study described in this section.

**Language Objectives:**

- Understand and correctly use terms relating to each branch of physics.

### Summary of Concepts:

physics: the study of the nature and properties of matter and energy. As you may recall, chemistry is the study of the composition and properties of matter, and how it can be changed from one substance to another. Physics is the study of matter, energy, and the relationships between them

Physics can be challenging to learn (and to teach) for a variety of reasons.

Yes, physics requires math.

### Notes:

physics: the study of the nature and properties of matter and energy, and the relationships among them.

### Branches of Physics

mechanics, including relativity: motion, forces, gravitation, and kinetic energy.

thermal physics: energy transferred and stored as the microscopic kinetic energy of the particles that substances are made of.

waves, including optics & acoustics: transfer of energy through space via interactions with the medium (substance) that the wave travels through. (Note, however, that electromagnetic waves such as light serve as their own medium.)

electricity & magnetism: forces and transfer of energy due to interactions among charged particles.

atomic & particle physics and quantum mechanics (sometimes called “modern physics”): study of particles that matter is composed of, and interactions among them.

nuclear & high-energy particle physics: study of forces that affect the composition of the nucleus of an atom.

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**astrophysics:** study of the universe, including galaxies, solar systems, stars, planets, moons, *etc.*

Physics is also the basis of engineering, which is the design, building, development, and use of technology, including engines, machines, and structures.

High school physics classes cover a variety of these topics. Physics is the least regulated and structured of the major sciences taught in high school; in many school districts, nobody other than physics teachers actually knows what physics teachers do. This gives teachers a lot of flexibility to adjust the course according to students' needs

In most states, first-year physics courses cover mechanics in depth, and an introduction to waves, electricity, thermal physics and/or atomic & particle physics. AP<sup>®</sup> Physics 1 covers only mechanics, whereas AP<sup>®</sup> Physics 2 covers the remainder of these. These notes are divided the same way as the AP<sup>®</sup> courses; *Class Notes for Physics 1: Mechanics in Plain English* covers mechanics, and *Class Notes for Physics 2: Non-Mechanics Topics in Plain English* covers the other common topics covered in high-school physics.

### **Mechanics Topics Covered in These Notes**

- **kinematics (motion)**
  - motion
  - speed & velocity
  - acceleration
  - motion graphs
  - motion in multiple dimensions
  - circular/rotational motion
  - relative motion & special relativity
- **forces**
  - Newton's laws
  - types of forces, including tension, friction and drag
  - forces in multiple dimensions
  - torque (when a force causes rotation)
  - gravitation
- **mechanical energy**
  - kinetic energy
  - gravitational potential energy
  - work & conversion of mechanical energy between different forms
  - conservation of energy
  - power
  - rotational energy, work & power

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- **momentum**
  - collisions
  - conservation of momentum
  - angular momentum
- **simple harmonic motion**
  - springs
  - pendulums
- **fluids**
  - pressure
  - buoyancy
  - fluid flow
- **special relativity**
  - length contraction
  - time dilation
  - apparent mass

## What Makes Physics Hard to Learn?

On the one hand, physics at the high school level is easier to visualize than biology or chemistry. Much of biology is microscopic, and changes happen too slowly to observe. Chemistry is all sub-microscopic (*i.e.*, atoms are too small to see, even with a microscope), which makes it difficult to understand the connections between what you can observe and what is happening with the atoms. Distances and sizes in Earth and planetary science are too large to see without telescopes. High-school physics has the advantage that almost everything you will study are things you can see and interact with directly.

The biggest challenge with learning physics is that it is a mathematical science. Mathematics is the study of the rules and relationships that govern the universe; physics is the study of those laws in action. Physics *is* applied mathematics. Some branches of mathematics, such as calculus, were discovered in order to explain how physics works.

Throughout elementary, middle, and high school, math was largely focused on getting the right answer whether or not you actually understood what was going on. In many cases, you were taught to memorize procedures that produce correct answers, often with so little understanding of what the procedures were doing that you had no way of knowing whether you did a problem correctly or whether the answer made sense.

Ultimately, to understand physics, you really do need to ***understand*** the math required.

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### How Much Math Does Physics Require?

One concern that many high school students have is being able to do the math that is needed for physics.

**“On-level” (CP1) Physics:** requires algebra 1 and geometry, and some algebra 2.

**AP® and Honors Physics:** requires algebra 1, geometry, algebra 2 and a little bit of precalculus. The calculus-based AP® Physics C courses (which are the only ones that are useful if you intend to study physics or engineering in college) also require the equivalent of AP® Calculus BC.

**College Physics:** requires at minimum algebra 1, algebra 2, precalculus and single- and multi-variable calculus. Higher levels of physics (and engineering) also require more advanced topics, such as differential equations, partial differential equations, linear algebra, vector and tensor math, and transformations.

To understand physics, you really do need to fully and deeply *understand* these math topics.

### What Makes Physics Hard to Teach?

Teaching high school physics is challenging mostly because of the math. As the teacher, one of my jobs is to make sure you really do understand the math. This means that I will probably need to do a lot of back-filling, including fractions, ratios & proportions, and algebra 1 (equations and graphs). I will *review* what you need to know, but if you need more help than the review that I cover in class, you will probably need to come after school for extra help.

### The Problem With Using Calculators, PhotoMath, Desmos, AI, etc.

In your previous math and science classes where you were graded based on whether or not your answers were correct, you probably used “black box” technology—software and hardware tools that generate the answers to problems for you. However, the purpose of studying these topics in school is for you to understand them yourself.

If you give a three-year-old a hammer, the child will almost certainly break things with it, and will probably hurt himself or others in the process; it is unlikely that the child will learn how to use a hammer effectively in the way that it is intended to be used. The same is true with math-related software tools:

- If you only ever did multiplication and division problems on a calculator, it made algebra much harder, because you couldn’t immediately see where each step of a problem was going.
- If you only ever solved algebra problems using PhotoMath, it prevented you from learning which procedures apply to which problems, making it quite difficult to look at a problem and know how to solve it.
- If you only ever plotted graphs using Desmos, it prevented you from seeing a graph as anything other than a picture that somehow represents an equation.

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- If you only ever solved word problems using artificial intelligence (AI), it prevented you from learning the process of identifying what a problem is asking and how to systematically work out the answer.

Tools are great, but only to the extent that they make it more convenient to use the intelligence that you have already acquired. ***If you continually use tools in ways that prevent you from acquiring intelligence, you will never acquire the intelligence.***

Note also that in physics problems, finding the “correct” answer to a specific problem is never the ultimate goal. Learning the process that you need to use to solve problems is the goal; the answers to problems are simply a convenient way to check how well you have learned the process. ***If you have a homework paper (or even a test) full of correct answers that you don’t understand, you have failed the course, regardless of the grade that you receive.***

This means that you need to *be proactive* and *ask for help whenever you need it*.<sup>\*</sup> As the teacher, I promise to give you whatever help you need, as long as you are able to make the time to get it (usually by coming after school for extra help).

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<sup>\*</sup> Even if you are still learning English and it is hard to ask, *it is important that you do so anyway*. I promise that I will always be patient with you and do whatever I can to get the physics to make sense.

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