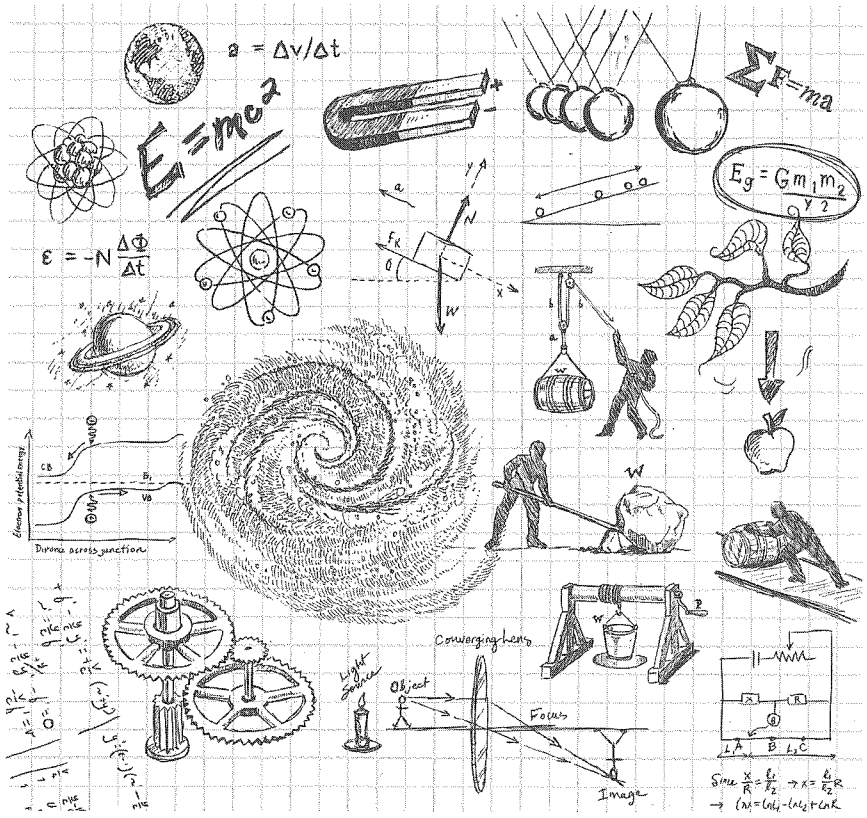
1 Skills, Methods, and the Nature of Physics

By the end of this chapter, you should be able to do the following:

- Describe the nature of physics
- Apply the skills and methods of physics including:
  - conduct appropriate experiments
  - systematically gather and organize data from experiments
  - produce and interpret graphs
  - verify relationships (e.g., linear, inverse, square, and inverse square) between variables
  - use models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
  - use appropriate units and metric prefixes

By the end of this chapter, you should know the meaning to these key terms:

- accuracy
- dependent variable
- experimental error
- independent variable
- law
- linear function
- model
- precision
- scalar quantities
- scientific method
- scientific notation
- slope
- uncertainty
- vector quantities
- *y*-intercept



In this chapter, you'll learn about the tools, skills, and techniques you'll be using as you study physics and about the nature of physics itself.

1.1 What is Physics?

Warm Up

This is probably your first formal physics course. In the space below, describe your definition of physics.

_____

_____

_____

Physics Explains the World

We live in an amazing place in our universe. In what scientists call the Goldilocks principle, we live on a planet that is just the right distance from the Sun, with just the right amount of water and just the right amount of atmosphere. Like Goldilocks in the fairy tale eating, sitting, and sleeping in the three little bears' home, Earth is just right to support life.

Yet there is much that we don't know about our planet. To study science is to be part of the enterprise of observing and collecting evidence of the world around us. The study of physics is part of this global activity. In fact, from the time you were a baby, you have been a physicist. Dropping food or a spoon from your baby chair was one of your first attempts to understand gravity. You probably also figured out how to get attention from an adult when you did this too, but let's focus on you being a little scientist. Now that you are a teenager you are beginning the process of formalizing your understanding of the world. Hopefully, this learning will never stop as there are many questions we do not have answers to and the wonder of discovering why things happen the way they do never gets boring. That is part of the excitement of physics — you are always asking why things happen.

Physics 11 will give you many opportunities to ask, "Why did that happen?" To find the answers to this and other questions, you will learn skills and processes to help you better understand concepts such as acceleration, force, waves, and special relativity. You will learn how to apply what you have learned in math class to solve problems or write clear, coherent explanations using the skills from English class. In physics class, you can apply the skills and concepts you have learned in other classes. Let's begin by looking at one method used to investigate and explain natural phenomena: the scientific method.

The Scientific Method

How do you approach the problems you encounter in everyday life? Think about beginning a new class at the start of the school year, for example. The first few days you make observations and collect data. You might not think of it this way, but when you observe your classmates, the classroom, and your teachers, you are making observations and collecting data. This process will inevitably lead you to make some decisions as you consider the best way to interact with this new environment. Who would you like for a partner in this class? Where do you want to sit? Are you likely to interact well with this particular teacher? You are drawing conclusions. This method of solving problems is called the **scientific method**. In future courses you may have an opportunity to discuss how the scientific method varies depending on the situation and the type of research being undertaken. For this course, an introduction to the scientific method is provided to give you a foundation to develop habits of thinking scientifically as you explore our world.

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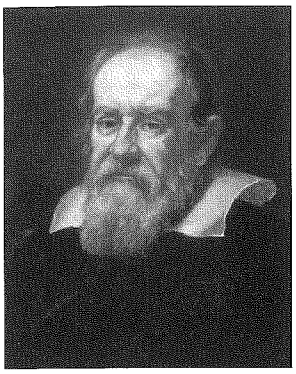

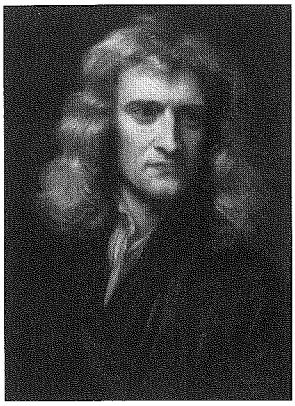

Figure 1.1.1 *Galileo (top) and Newton*

Four hundred years ago, scientists were very interested in understanding the world around them. There were hypotheses about why the Sun came up each day or why objects fell to the ground, but they were not based on evidence. Two physicists who used the scientific method to support their hypotheses were the Italian Galileo Galilei (1564–1642) and the Englishman Sir Isaac Newton (1642–1727).

Both Galileo and Newton provided insights into how our universe works on some fundamental principles. Galileo used evidence from his observations of planetary movement to support the idea that Earth revolved around the Sun. However, he was forced to deny this conclusion when put on trial. Eventually, his evidence was accepted as correct and we now consider Galileo one of the fathers of modern physics. Sir Isaac Newton, also considered one of the fathers of modern physics, was the first to describe motion and gravity. In this course, you will be introduced to his three laws of motion and the universal law of gravitation. Both ideas form a foundation for classical physics. Like many others that followed, both Galileo and Newton made their discoveries through careful observation, the collection of evidence, and interpretations based on that evidence.

Different groups of scientists outline the parts of the scientific method in different ways. Here is one example, illustrating its steps.

Steps of the Scientific Method

1. **Observation**: Collection of data. **Quantitative** observation has numbers or quantities associated with it. **Qualitative** observation describes qualities or changes in the quality of matter including, for example, a substance's colour, odour, or physical state.

2. **Statement of a hypothesis**: Formulation of a statement in an "if…then…" format that explains the observations.

3. **Experimentation**: Design and carry out a procedure to determine whether the hypothesis accurately explains the observations. After making a set of observations and formulating a hypothesis, scientists devise an experiment. During the experiment they carefully record additional observations. Depending on the results of the experiment, the hypothesis may be adjusted and experiments repeated to collect new observations many times.

   Sometimes the results of an experiment differ from what was expected. There are a variety of reasons this might happen. Things that contribute to such differences are called **sources of error**. They can include random errors over which the experimenter has no control and processes or equipment that can be adjusted, such as inaccurate measuring instruments. You will learn more about sources of error in experiments in section 1.3.

4. **Statement of a Theory**: Statement of an explanation for the hypotheses being investigated. Once enough information has been collected from a series of experiments, a reasoned and coherent explanation called a theory may be deduced. This theory may lead to a **model** that helps us understand the theory. A model is usually a simplified description or representation of a theory or phenomenon that can help us study it. Sometimes the scientific method leads to a **law**, which is a general statement of fact, without an accompanying set of explanations.

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Quick Check

1. What is the difference between a law and a theory?

2. What are the fundamental steps of the scientific method?

3. Classify the following observations as quantitative or qualitative by placing a checkmark in the correct column. **Hint:** Look at each syllable of those words: quantitative and qualitative. What do they seem to mean?

Observation	Quantitative	Qualitative
Acceleration due to gravity is 9.8 m/s^2.		
A rocket travels faster than fighter jet.		
The density of scandium metal is 2.989 g/cm^3.		
Copper metal can be used for wire to conduct electricity.		
Mass and velocity determine the momentum in an object.		
Zinc has a specific heat capacity of 388 J/(kg·K).		
The force applied to the soccer ball was 50 N.		

4. Use the steps of the scientific method to design a test for the following hypotheses:
   (a) If cardboard is used to insulate a cup, it will keep a hot drink warmer.

   (b) If vegetable oil is used to grease a wheel, the wheel will turn faster.

   (c) If hot water is placed in ice cube trays, the water will freeze faster.

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The Many Faces of Physics

There are many different areas of study in the field of physics. Figure 1.1.2 gives an overview of the four main areas. Notice how the areas of study can be classified by two factors: size and speed. These two factors loosely describe the general themes studied in each field. For example, this course focusses mainly classical mechanics, which involves relatively large objects and slow speeds.

A quick Internet search will show you many different ways to classify the areas of study within physics. The search will also show a new trend in the study of sciences, a trend that can have an impact on your future. Rather than working in one area of study or even within one discipline such as physics, biology, or chemistry, inter-disciplinary studies are becoming common. For example, an understanding of physics and biology might allow you to work in the area of biomechanics, which is the study of how the human muscles and bones work. Or maybe you will combine biology and physics to study exobiology, the study of life beyond the Earth's atmosphere and on other planets.

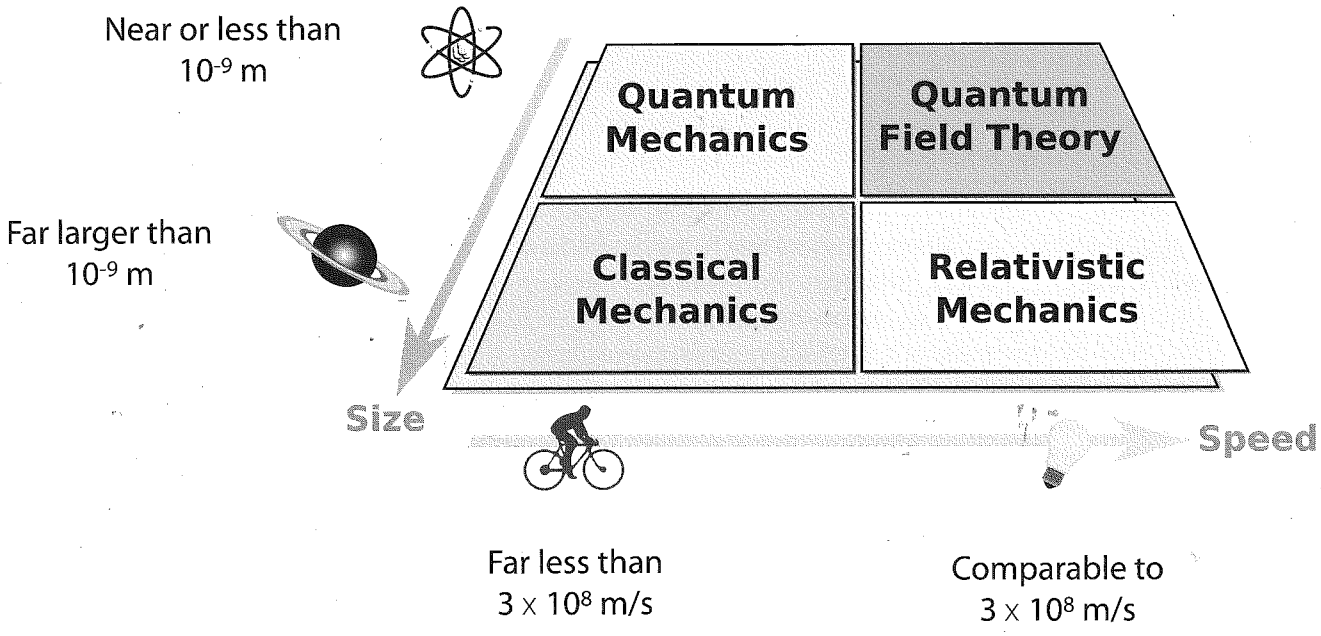

Figure 1.1.2 *The four main areas of physics. (Credit: Yassine Mrabet)*