Course Learning Outcomes for Unit I

Upon completion of this unit, students should be able to:

1. Describe the system of units for various physical quantities.
   1.1 Identify the components of measuring speed and velocity.
   1.2 Interpret the relationship between displacement, velocity, and time.

2. Illustrate the scientific method within everyday situations.
   2.1 Investigate how constant-paced linear motion is depicted.
   2.2 Calculate the velocity using data in the conceptual experiment.

Required Unit Resources

Chapter 1: Introduction and Mathematical Concepts

Chapter 2: Kinematics in One Dimension

Unit Lesson

Short History of Physics

What is physics? *Physics* is the basis of other fields of science and encompasses studying about the matter, energy, and principles of the governing forces between objects, particles, and more. However, the history of physics is not that long! In ancient times, scholars led by Aristotle in Greece about 2,300 years ago were trying to explain physical phenomena using the philosophical method. Pioneering research using experiments was opened by Galileo Galilei in the 16th century, and classical physics bloomed with Isaac Newton. His achievements were huge in many fields of science such as optics, astronomy, chemistry, and mathematics in addition to physics.

Newtonian mechanics work perfectly when we try to describe the macroscopic world we live in; however, they fail when we want to explain microscopic phenomena such as X-ray and nuclear radioactivity. In order to explain the microscopic world, modern physics like quantum mechanics is needed. A central idea of quantum mechanics is the quantization of all types of energy. The basis of modern physics is, of course, classical physics, and without concepts of classical physics, we could never understand modern physics. This makes classical mechanics a very important subject to master.

Galileo (1564–1642) was an Italian scientist and is often called the father of physics. He opened a new world of science through experiments. Unlike Aristotle who ruled the world of science for over 1,000 years, he established physics based on observation and measurements. In order to understand relationships between physical elements, he performed experiments with falling objects, projectiles, inclined planes, and pendulums (Hewitt, 2015). He founded a new view of gravity and overturned old, incorrect ideas about relationships between mass, velocity, and acceleration in motion.

Galileo described important and basic concepts of physics such as inertia and acceleration while Newton organized the laws of motion neatly. That is, the base of physics was prepared by Galileo, and the peak of classical physics was made by Newton.

According to Aristotle’s logic, there is no motion unless a force is involved; however, that is not true, and this is proven by experiments. Once the object is moving, there is a tendency that it keeps it moving without any forces. This is called inertia and is the same as the first law of Newton. Unless there are no external forces and frictions, the object has the property to keep the current state. That is, if an object is in a static motion, it keeps still without motion. If it is in motion, it continues to move. Here, the mass is a measure of inertia. The more massive the object, the greater the inertia it has. Mass and weight are different concepts. Weight is mass times gravitational acceleration; weight is a force.

If you roll a ball on a plane inclined at various angles, you find that the ball on a higher angled plane arrives faster to the bottom than that on a lower angled plane. However, the final speeds of balls at the bottom are the same regardless of different inclined angles. Galileo introduced the concept of acceleration, the rate of velocity. The acceleration is the velocity change at a certain time. He calculated the increased velocity per time of the ball; its acceleration was constant.

Which objects will hit the ground first, the heavier or the lighter ones? Why is that? If we perform this experiment in the air, the heavier object hits the ground first because of air resistance; however, they hit the ground at the same time in a vacuum. You can watch a demonstration of this in the video listed in the Suggested Unit Resources area of this unit.

In other words, the free-fall objects are merely dependent on the gravity of the Earth. The free-fall object gains a velocity of approximately 10 meters per second. The value of gravitational acceleration on the surface of the Earth is measured as $9.8 m/s^2$, which is about $10 m/s^2$.

Dimensional Analysis

Dimensional analysis is a very useful tool to find out unknown physical formulas or quantities. For instance, say you are trying to figure out the relation among speed (*s*), distance (*d*), and time (*t*). What is the speed when you travel a distance of 100 km for an hour? Maybe you already know that speed should be calculated by traveled distance divided by elapsed time, but let's assume we do not know a proper formula. We can check the equation/relation through dimensional analysis. Note that an equation must have the same dimension on both sides.

Can you justify which formula is a correct one in the following equations?

1. $s = dt$, or
2. $d = st$, or
3. $t = sd$?

The three basic dimensions are a length (*L*), mass (*M*), and time (*T*). We can express any physical quantities using the above. That is, the dimension of distance (*d*) is length [*L*], the dimension of speed (*s*) is [*L*] / [*T*], and the dimension of time (*t*) is [*T*].

1. $s = dt$ → $[L] / [T] = [L] \times [T]$ =➔ Wrong!
2. $d = st$ → $[L] = [L] / [T] \times [T]$ =➔ Correct!
3. $t = sd$ → $[T] = [L] / [T] \times [L]$ =➔ Wrong!

So, we found that the correct equation is $d = st$. The traveled distance (*d*) can be calculated by the speed of an object (*s*) times the traveled time (*t*).

If we use a different system of units, then it would be very confusing, so it is necessary to adopt normalized unit systems. Thus, we are using the international system of units (SI units). The SI unit of length is meter, time is second, and mass is kilogram (Cutnell et al., 2022). See the chart below for the definitions of these units.

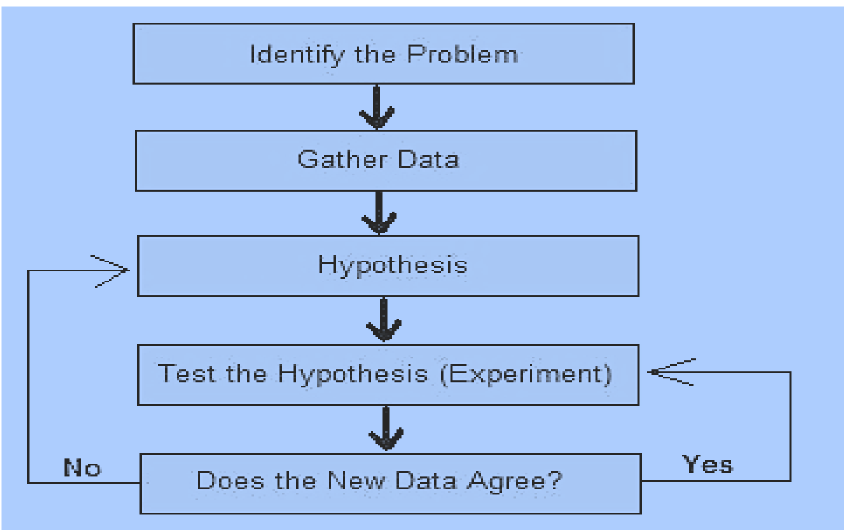
Measure	SI Unit	Definition
Length	Meter (m)	The distance traveled by light in a vacuum in 1 / 299,792,458 second
Time	Second (s)	The time it takes for radiation from a ^{133}Cs, cesium atom to complete 9,192,631,770 cycles of oscillation

Mass	Kilogram (kg)	The mass of the international standard body (a cylinder of platinum-iridium alloy) preserved at Sevres, France
Temperature	Kelvin (K)	1 / 273.16 of the thermodynamic temperature of the triple point of water

Science Versus Pseudoscience

Astrology is not science! It is pseudoscience. Pseudo means false in Greek. Pseudoscience is just pretending to be an actual science. It is based on many scientific ideas, but it fails to explain those using scientific laws. Astrology claims that there is a relationship between humans and celestial objects such as planets, stars, and moons. An essential property of science is that it must be tested and verified. Astrologers never predict a person's future! There is no logical and physical evidence that a person's life is affected based on a horoscope.

Scientific Method



The steps of the scientific method
(CK-12 Foundation, 2010)

Scientific inquiry must follow the scientific method. The first step of this method is to create a logical statement (or a question) that defines the problems. To define the problem correctly, background research, observations, and a collection of appropriate knowledge are necessary and helpful. The next step is to state or construct a hypothesis. Write a logical hypothesis, a plausible momentary justification or an educated guess, that may explain the question smoothly based on all the current knowledge and information. Then, test the hypothesis and analyze the result. Next, perform an experiment, analyze the result, and develop an applicable explanation that makes sense. Finally, make a conclusion or modify the question and repeat the above steps. Draw a coherent conclusion after a deep consideration based upon the results of analysis and development. Also, point out any areas about which you have suggestions or further questions.

Velocity/Speed and Acceleration

A fundamental job of physics is to describe the motion of an object. In order to do this, we need some basic elements to depict it. These elements are displacement, velocity, and acceleration. Here, we will focus on the kinematical point of view without consideration of a source that yields the motion. Kinematics involves the description of motion without examining the forces that produce the motion. Dynamics, on the other hand, involves an examination of both a description of motion and the forces that produce it, so we can say that physics is all about kinematics and dynamics.

Vectors are quantities that are fully described by both a magnitude and a direction. Meanwhile, *scalars* are quantities that are fully described by a magnitude alone. For instance, the number of gallons of gasoline in a tank, the temperature, your weight, or the population of a country is a scalar quantity. It is just a number. Considering a direction for them is meaningless.

Velocity is the rate at which the position of an object changes. Velocity is a vector quantity because it has direction. Speed has no direction, so it is a scalar quantity that refers to how fast an object is moving. A fast-moving object has a high speed while a slow-moving object has a low speed. An object with no movement at all has a zero speed. That is, velocity is simply the speed with a direction.

The average speed of an object is the distance traveled by the object divided by the time required to cover the distance.

Distance = Speed x Time

Displacement = Velocity x Time

Acceleration is the rate at which the velocity is changing. The average acceleration is a vector. It equals the change in the velocity divided by the elapsed time. The change in velocity is the final velocity minus the initial velocity. When the elapsed time becomes infinitesimally small, the average acceleration becomes equal to the instantaneous acceleration.

Both velocity and speed tell how fast the object is. In detail, velocity is a vector that has direction and magnitude. Speed is a scalar that has only magnitude. The speedometer on a car indicates the speed at that moment. As the velocity increases, decreases, and the direction changes, the acceleration varies. In that sense, the car has three systems of acceleration. The gas pedal (accelerator) increases velocity, the brakes decrease it, and the steering wheel controls the direction of movement.

You can view a more detailed explanation by viewing the video *Vectors and Scalars* (you can also view the transcript for the video *Vectors and Scalars*). It will also help when you solve questions in the Unit I Project.

References

CK-12 Foundation. (2010). *The scientific method* [Image]. Wikimedia. https://commons.wikimedia.org/wiki/File:The_Scientific_Method.jpg

Cutnell, J. D., Johnson, K. W., Young, D., & Stadler, S. (2022). *Physics* (12th ed.). Wiley.

Hewitt, P. G. (2015). *Conceptual physics* (12th ed.). Pearson.

Suggested Unit Resources

In order to access the following resource, click the link below.

The video below demonstrates how two objects fall at the same speed in a vacuum. In this case, the experiment takes place on the moon.

NASASolarSystem. (2006, July 5). *Feather & hammer drop on moon* [Video]. YouTube. https://www.youtube.com/watch?v=5C5_dOEyAfk

To view closed-captioning for this video, click the CC at the bottom of the video.

Learning Activities (Nongraded)

Nongraded Learning Activities are provided to aid students in their course of study. You do not have to submit them. If you have questions, contact your instructor for further guidance and information.

1. Solve Questions 59–65 under Physics in Biology, Medicine, and Sports in Chapter 1 of your eTextbook.
2. Solve Questions 74–81 under Physics in Biology, Medicine, and Sports in Chapter 2 of your eTextbook.