kiron

Study Guide

ME_Ph1: Physics

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Foreword

Purpose

The Study Guide is designed as a written script that walks you through the topics within a study unit, called Module, in your Kiron studies and provide links to additional open educational resources. The purpose of this document is to accompany you while you are studying the online courses in the module. It is not a replacement of any course or content within the modules, thus it does not grant you any course completion. However, using it helps you progress in an easier way through your studies.

Structure

The Study Guide introduces the subjects in the corresponding modules and connects to the relevant parts in the online courses (MOOCs) that you have to take in order to complete the module. It provides links to additional video lectures, written pieces, other kinds of enriching materials and suggested exercises from open educational resources to elaborate on the topics.

Iconography

This document uses a set of standard icons to mark and make it easier to follow the important external resources that are linked in the text body. Below are the occasions and meanings for these icons:


Hints, suggestions and other important notes to check


Book, web page or other written material


Reference to the Kiron Campus or to the MOOC in the module


Applet, simulation or other interactive labs resource


Discussion in Kiron Forum, Google Classroom or Google Hangouts


Exercise or assessment resource


End of a chapter


Video lecture or tutorial resource

Table of Contents

Introduction

Welcome to the very first module of your Mechanical Engineering studies at Kiron: **Physics!**

The purpose of this Study Guide is to give you a first impression of the fundamental subjects in the Physics Module and to familiarize you with the central concepts being taught in the courses. As you advance in your studies, you will encounter these topics continuously and expand your knowledge with additional theories and practical use cases from the engineering world.

Contents and Learning Outcomes

The [Physics Module] covers the essential theories, laws and mathematical foundations of classical mechanics, electromagnetism and optics. Accordingly it is divided into five chapters covering the following subjects:

1. Motion: Linear and rotational motion, energy, momentum, gravity, oscillations
2. Electricity and Magnetism: Electrostatics, magnetism and induction, capacitance
3. Waves and Light: Characteristics of waves and light, diffraction and interference
4. Fluids and Thermodynamics: Fluid characteristics, buoyancy, temperature and gas laws
5. Atomic Physics: Atomic structure, atomic transitions

After completing the courses in this module, you will be able to:

- explain force, momentum, gravity and analyze their effects on a point mass
- explain the conservation of energy through the concepts of energy and work
- differentiate types of oscillations and describe the simple harmonic motion
- describe the basic wave phenomena and identify them in different physical systems
- describe the nature of light and its propagation both as a wave and a particle
- demonstrate the image formation through lenses and mirrors
- define the electromagnetic properties and concepts such as charge, field, potential, current and state the laws of electromagnetism
- describe the physical properties of the atomic nucleus and the origin of radioactivity

Courses

The expected learning outcomes of the module are covered by four different online courses. You are expected to complete all of these courses to complete the Physics Module and earn Kiron Credit Points.

The first course in the module is How Things Work: An Introduction to Physics (HTW) from University of Virginia, USA. One way to think about physics is as descriptions of *How Things*, from an atom to the universe, *Work*. A fundamental aspect of any physical investigation is motion. Highly illustrative and rich with experiments, this introductory course explores the motion of everyday objects. In particular, you will develop an intuition for the basic concepts and properties such as velocity, acceleration, force and energy conservation, through which motion is analyzed. This course has:

- **8 units** with **9 hours** of video lectures in total.
- graded multiple-choice quizzes for each unit.
- one graded multiple-choice final exam at the end of the course.
- an estimated workload around **13 hours**.

The second course in the module is RiceX: AP® Physics 1 (AP1) from Rice University, USA. This course constitutes the core of the Physics module. The main purpose of AP1 is to enable you to cultivate one of the most central handicrafts for physicists and engineers: given a concrete problem, how to pose and solve the relevant mathematical equations in the simplest way possible. Problem solving oriented and mathematically formalized, this course will introduce you to the classical problems of physics in three of its fundamental fields: Kinematics, Electricity and Waves. In each unit, a video lecture first introduces a topic, presents the relevant equations and illustrates it with an experiment. Then, in a tutorial video, an exercise is solved step by step. This is only to prepare you for the main part of this unit: solving problems independently. This course has:

- **18 units** with **12 hours** of video lectures in total.
- ungraded exercise sets, graded problem sets and digital labs for each unit.
- one graded multiple-choice final exam at the end of the course.
- an estimated workload around **72 hours**.

The third course in the module is AP® Physics 1: Challenging Concepts (CC1) from Davidson Next, a partnership among Davidson College, the College Board, edX, 2Revolutions and Charlotte-Mecklenburg Schools in the USA. This is the first of two-course series on challenging concepts in introductory physics. This series is included in the module to deepen your understanding of the topics you engaged with in the AP1 course. While you were primarily thinking in terms of the relevant mathematical equations in AP1, in these Challenging Concepts series you will concentrate on the construction, understanding and analysis of diagrams and graphs as a way to represent and solve physical problems. Moreover, you will learn how they correspond to the mathematical equations, with which you are already familiar. You will revisit all the topics you encountered in AP1 in a complementary way. This course has:

- **8 units** with **3,5 hours** of video lectures in total.
- graded problem sets, quizzes and additional assignments for each unit.
- one graded multiple-choice final exam at the end of the course.
- an estimated workload of around **32 hours**.

The fourth and final course in the module is the second part of the Challenging Concepts series from Davidson Next, AP® Physics 2: Challenging Concepts (CC2). You will further develop your capacities to analyze and solve problems in physics using graphical representations. In this course, however, you will explore the more advanced topics of electromagnetism, thermodynamics, liquids and light. In the latter parts of your studies, you will deal with all of these topics in a much more thorough manner. As with the module as a whole, the main purpose of this final course is to provide you with a solid introduction and a preparatory bridge for some of your next courses. This course has:

- **9 units** with **4 hours** of video lectures in total.
- graded problem sets, quizzes and additional assignments for each unit.
- one graded multiple-choice final exam at the end of the course.
- an estimated workload around **36 hours**.

Apart from the first course, this module is composed of three physics courses that aim to prepare for the Advanced Placement (AP®) Program in the USA. This program enables high school students to take university level exams, thus earn credit points for their future studies at the university. While we found these courses to be the most suitable for the physics fundamentals in the beginning of Mechanical Engineering studies at Kiron, kindly note that Kiron has no cooperation with the AP® Program and the AP® Program does not have any connection to Kiron's partnerships with universities.

Prerequisites

Before starting with this module, you are recommended to have high school level knowledge in mathematics and physics.

If none of the mentioned terms or concepts in Contents and Learning Outcomes are familiar to you or you are unsure about your knowledge level from high school, you should check our preparatory courses for physics. You can find these courses under the Physics - Prep Module in the Prep & Language section in the Kiron Campus.

If only some of the mentioned topics and learning outcomes are not clear for you right now, do not worry. You will become more familiar with the terminology and have the possibility to check how you perform throughout the courses.

Now please make sure that you checked the exact session dates of the courses in the Module and enrolled in the courses on both Kiron Campus and external platforms. If you are having difficulties, please have a look at the support articles on Kiron Help Center. Here are some helpful articles:

- How do I use the Kiron Campus?
- How do I enroll in a course?
- When does my course start?
- How to register to the different MOOC platforms

Additional Resources

In this Study Guide, we will have links to additional video and text materials to enhance your understanding. Fortunately there are several good open educational resources available for physics. They discuss all the subjects that are dealt with in this module in a coherent and illustrative manner. They also contain additional themes that go beyond its explicit scope. Here is a list of the resources that we often refer to in this Study Guide:

- Open online textbooks from OpenStax at Rice University
    - College Physics. This book is probably the best one to start with. It presents the subjects in a similar manner to that used in the Moocs and in the same level of difficulty.
    - University Physics: Volume 1, Volume 2. This two volume book discusses the same subjects as College Physics but in a more advanced manner that

presupposes knowledge in calculus. It corresponds to a university level physics course.
    - Algebra and Trigonometry. This book is a great source for the mathematics used in the module.
- Video lectures, articles and exercises from Khan Academy
    - The sections we will use often in this Study Guide are Physics, AP® Physics 1, AP® Physics 2
- Interactive simulations for physics and mathematics from PhET by University of Colorado Boulder
    - We will often refer to the wide collection of simulations and digital lab exercises from the Physics section

However, the internet is full of additional open access resources on physics. Some of those are linked in this Study Guide as well, but you might like to explore the rest by yourself. Here is a selection of them:

- A large collection of video lectures and tutorials on many different science subjects including physics: iLectureOnline
- A dedicated online physics classroom with a large collection of written materials, interactive tools, exercises and experiments: Physics Classroom
- An encyclopedia for definitions, theories and formulas physics: Eric Weisstein's World of Physics
- A large collection of interactive illustrations, explorations and problems for introductory physics subjects by Wolfgang Christian and Mario Belloni: Physlet® Physics 2E
- A map of concepts in physics and accompanying materials in different formats by Carl R. Nave: HyperPhysics

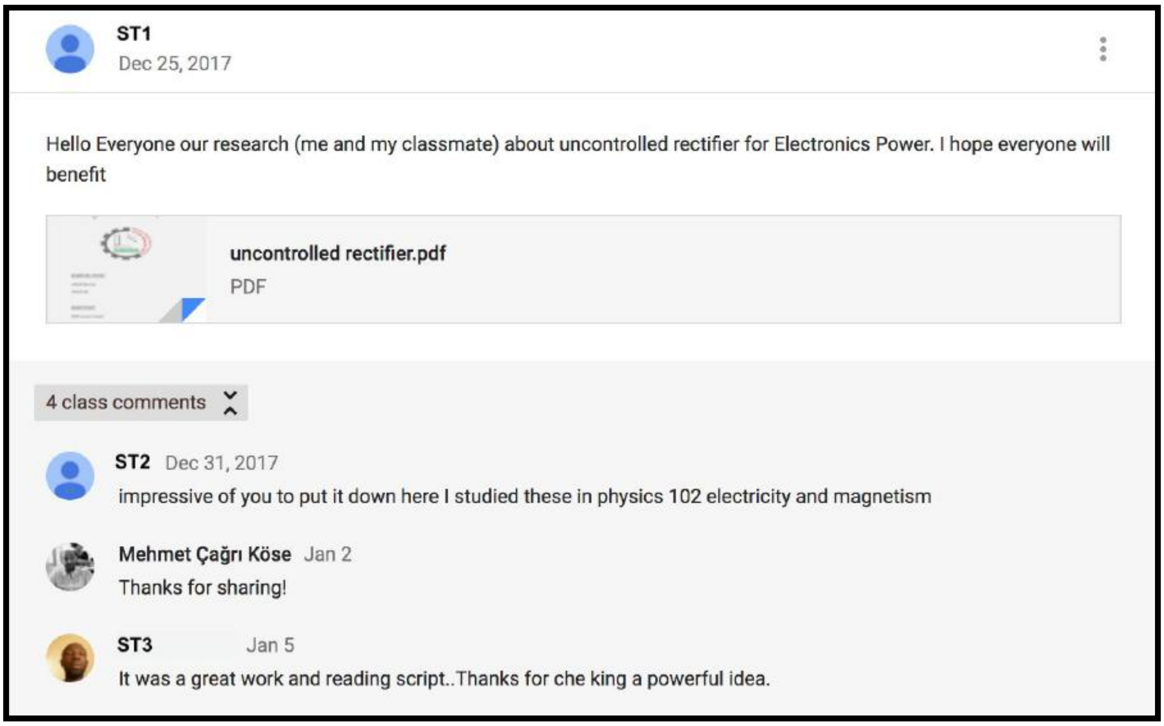
While you can share your feedback on these materials with us and your classmates in the Physics Classroom, questions and errors about these external contents should be addressed to their individual producers and owners.

Communication

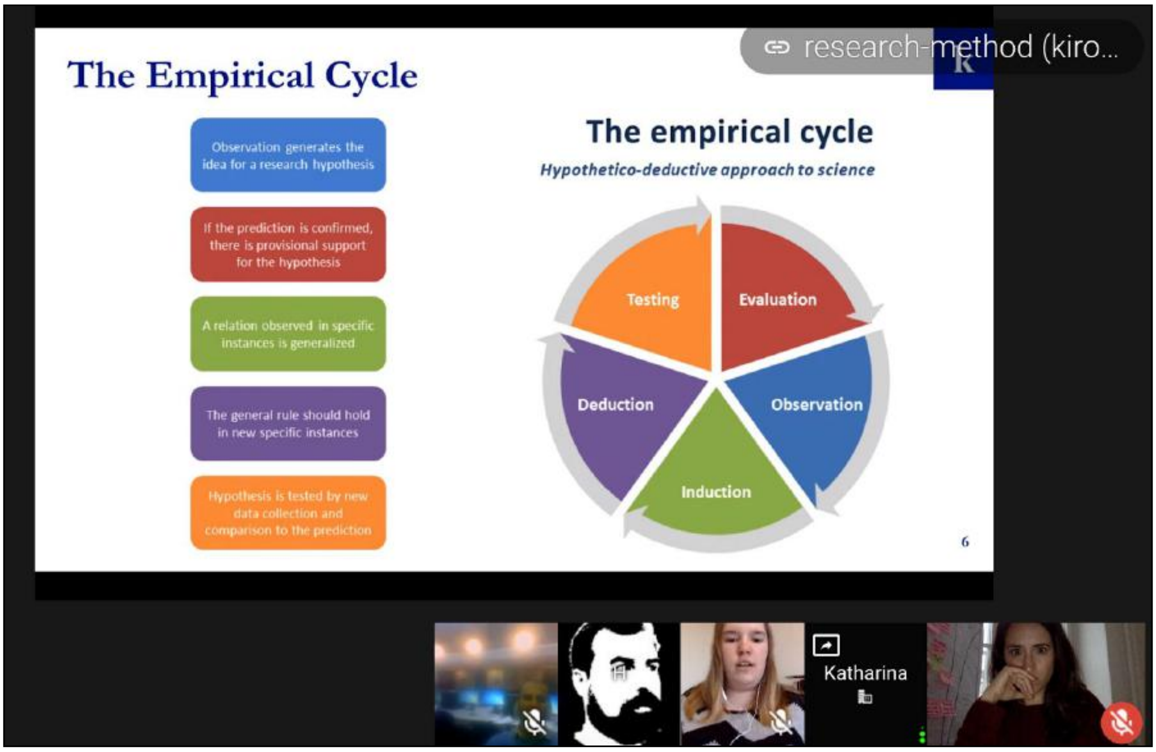
The main communication channels for sharing feedback about this document and about the Physics Module itself are the dedicated Google Classroom and Google Hangouts. There you can ask your questions regarding the content in this document, in the online courses or about physics in general.

There are two ways to communicate:

- You can create a post or comment in the Classroom stream.



- You can use the Hangouts group for instant messaging, audio or video chatting.



Please join these channels manually if you have not already been added already. You can find the instructions for joining the Google Classroom in this video, Physics Classroom. In addition you can check this page to learn how to connect with your class in a Google Classroom and this page to learn how to use Google Hangouts for chatting and making audio or video calls.

In addition to the above mentioned channels, some content from the Classroom may be made available in the Kiron Forum for other students too. Feel free to join the discussion in the Physics Category in the Forum as well.

Technical Requirements

This Study Guide is provided in digital format and includes links to external documents or web pages that require a computer or a mobile device with internet access and an internet browser. Some additional software and hardware technologies (e.g. portable document format [PDF] viewer, platform support for Java, HTML5 and Flash, Google Hangouts extension, headset with microphone) may be required for accessing the courses, for additional educational resources or for communication purposes.

Chapter 1 - Motion

Motion is one of the most fundamental subjects in mechanical engineering and in physics as a whole. In this chapter, we want to learn how to describe and make predictions about the motion of everyday life objects in terms of physics. A moving car for example; how can one calculate the distance a car travels at a certain time or the time it takes a falling object to reach the ground?
The physical theory that deals with motion was developed in the 17th century by Isaac Newton and is commonly known as **classical mechanics**. This theory enables us to describe the motion of objects with a defined mass under the influence of certain forces. The main task of classical mechanics is to predict the position of an object at any point in time. Although formalized a bit differently today, this theory is still used as the basis for solving many problems in mechanical engineering.
This chapter is divided into six units which, all together, will give you an overview and a first-hand experience of the basic concepts, laws and problems of motion. These study units combine video lectures from AP® Physics 1 (AP1) and the first of the Challenging Concepts (CC1) courses.

At the end of this chapter, you will be able to:

- explain the basic concepts of kinematics and the concept of force.
- state Newton's three Laws of Motion.
- define Newton's Law of Gravity and describe its effect on a point mass.
- solve one and two dimensional problems in kinematics.
- describe the concepts of mechanical energy, work and momentum.
- explain and apply the laws for conservation of energy and momentum.
- describe the basic modes of harmonic oscillation.

One of the biggest advantages in the study of motion, and of classical mechanics in general, is its intuitive character. Hence, in the first unit of this chapter, we would like to use this advantage and introduce you to the whole subject in a very general and intuitive manner.

The general introduction is given in the first course in the module: How Things Work: An Introduction to Physics. It is important to complete this course to develop an intuition about the initial subjects of this module. The following units will then deal with all the topics from this course more thoroughly and formally with links from the next courses in the module. Now please start the course and complete it before moving on to the rest of the module and this document. Beware that it can take around 10-15 hours in total to complete it.

Reading material for this chapter can be found in College Physics: Chapters 2-10.

In this chapter and throughout this module, we will often refer to the helpful video lectures of Khan Academy: Physics.

Another resource that will be referred to in this chapter and also in your courses is the collection of interactive simulations for Motion.

At the end of each study unit in this module, you will also find links to relevant additional resources. Feel free to check the Additional Resources section for exploring more on your own.

Linear Motion

After getting an overall intuitive introduction to the subject, we are now ready to move on to the mathematical description of motion. We start with the most basic type of motion. The linear motion refers to one-dimensional motion of an object along a straight line. Its physical description is based on Newton's first law and in particular on the concepts of position, velocity and acceleration. Such a description is called **kinematics** and is the subject of the first section. Then we will introduce the concept of force and in the final section discuss a bit more complex forms of linear motion.

Kinematics

As you saw in the introduction unit, Newton's first law states that the velocity (direction and speed) of an object, not affected by an external force, does not change. A change in velocity over time is called acceleration, which is the main concept of this section and in particular, its relation to position and velocity.

Kinematics is the description of motion as a function of time solely in terms of these concepts. It considers neither the mass of an object nor the forces that affect it. As such, it constitutes the basis for more complex forms of motion you will encounter later. This part is composed of the two study units: AP1 - 1D Kinematics and CC1 - Acceleration.

Force

Did you ever encounter an object that moves without being affected by its environment? Such a situation is quite rare, isn't it? We hence need a concept that will enable us to take the influence of the object's surroundings into consideration. This is the purpose of the concept of force which we shall discuss here. As you just saw, position, velocity and acceleration are vector properties inherent to the object itself, in so far as it is localized as a point in a coordinate system. Force, on the other hand, is an independent vector quantity that affects the object from the outside. Thus the problem becomes more complex and reads: given an object moving under a certain influence from its environment how can we determine its position at any given point in time? Mathematically, as you probably know, Newton's second law is formulated as an equation that relates force to the product of acceleration and mass.

Before you start, think about few physical forces you know and the way in which they affect the motion of objects that have a different mass. Do not forget that no effect is also a kind of effect. Now start working on the following two study units: AP1 - Forces and CC1 - Force Diagrams.

Two Dimensional Motion

We want to move forward and discuss a bit more challenging situations. Think, for example, about children that play with a ball by passing it around. How can we describe the motion of the ball from the moment one child throws it until another catches it?

As we know from experience, the ball does not move along a straight line. Its motion resembles something like an arch. However, as you shall see in this unit, it can be described as a composition of two linear motions. Take a moment and think how can it could be done. Now continue with this section's study units: AP1 - 2D Kinematics and CC1 - Free Fall and Projectile Motion.

The video lectures from Khan Academy on One Dimensional Motion explain the subject of this unit further.

Additionally, the PhET Simulations for Forces in 1D, Motion in 2D and Projectile Motion will help you to develop a better intuition of the concepts we introduced in this unit.

The Challenging Concepts courses offer a handful of links to additional resources for each study unit under the title Student Resources. It is worthwhile checking them out while you are working on these courses.

Energy and Momentum

When faced with a physical problem, finding an easy way for solving it requires great skill. In physics, many situations - or systems as they are often referred to - have inherent properties that can be very useful for concrete calculations. One such property is the tendency to have some quantities remain constant, despite the fact that the system is overgoing a change. This is known as the conservation principle. For example, if you engage in an intensive sports activity for a long time you will lose some of your body's weight. Your height, however, will remain the same, i.e. be conserved.

The discovery that, in closed systems, the magnitude of energy remains constant became one of the most fundamental principles in all of physics. In such systems, the momentum also remains constant. The principle of conservation gives a great example of how physics can often be counter-intuitive. Would you trust your own intuition or a physical law? Check out the Classroom Discussion: Human Intuition vs. Physical laws? and share your thoughts with your fellow students.

We will start this unit by understanding what both concepts actually mean and discussing their formal definition and characteristics. Then we will explore the concepts the principle of their conservation. In particular, we will experience how they can make certain calculations much easier compared with the kinematical equations you saw above. We start with energy.

Mechanical Energy

Energy is one of the most central concepts in all of physics. In the last century and as a result of path-breaking theories like quantum mechanics, many physical concepts were proven to be insufficient. In contrast to them, the generic quality of energy and the principle of its conservation were reaffirmed over and again. In this unit, AP1 - Energy, we focus on mechanical energy, that is the elements of energy that are directly related to the object's motion. The basic elements of mechanical energy are kinetic and potential energy.

A very important concept that is directly related to energy is work, which describes how the transfer of energy causes change. In addition to these concepts, this section will also discuss the application of the principle of energy conservation to problems of motion.

Linear Momentum

Linear Momentum, represented by the letter p, is a vector quantity defined as the product of an object's mass and velocity, p=mv. The principle of the conservation of momentum is very helpful in many cases. In particular, in those cases in which the system is composed of more than one object.

Before starting with the two corresponding lectures, AP1 - Momentum and CC1 - Momentum, try to rewrite Newton's second law using momentum instead of acceleration. Generalizing these considerations, try to define the systems for which the principle of momentum conservation does not hold.

Collisions

We now want to summarize what we have learned in this unit by considering a system in which both the momentum and energy are conserved. The collision of two or more objects, billiard balls, for example, is a great illustrative example. Making calculations for this kind of systems can be quite complicated. Any idea what can make it easier? Let us do a small thought experience:

Imagine that you hold four balls in your hands in the following order from bottom to top: a bowling ball, a basketball, a medium size rubber ball and a tennis ball on the top. Can you tell what will happen after you let them fall? Check out the Classroom Discussion: Collisions.

Now please proceed to the following lecture in your course and complete it before moving on to the assessments: AP1 - Collisions

You can find some additional video materials for energy, linear momentum and their conservation on Khan Academy: Energy and Work, Momentum and Impulse.

Feel free to experiment what you learn in the PhET simulations: Energy Skate Park, Collision Lab.

This is a good time to pause and see how well you understand the subjects so far. Please review your notes and learning materials before doing the following assignment for the chapter's first two units: AP1 - Units 1.1-1.2: Assessment.

Rotational Motion

A good scientific theory must be general enough to cover a large variety of cases. In this unit, you will learn how rotational motion can be described using an equivalent apparatus to the one we used so far to describe linear motion. This means that we must define the basic concepts of rotational motion in such a way that they become equivalent to the terms of linear motion we already know. After introducing these concepts and understanding what this equivalence precisely means, you will see how the tools you acquired in the previous two units can be applied to describe rotational motion.

Kinematics

As an introduction to rotational kinematics, we want to learn how to describe its most simple type: an object that rotates around a fixed point. We call this a circular motion. Before moving to the first study unit, AP1 - Circular Motion, think about some circular motions you know. Above, we considered an object that rotates around a fixed point and defined the basic notions that enable us to describe its motion.

In the following units, AP1 - Rotational Kinematics and CC1 - Rotational Motion, we will go a step further and introduce the concepts of torque and moment of inertia which are the rotational equivalents of force and mass we already know. We will also learn to describe the motion of objects that combine both linear and rotational motion, like that of a moving bicycle wheel. Finally, we will see how to describe mechanical energy in a rotational motion and how to use the principle of its conservation.

Conservation of Angular Momentum

The momentum for a linear motion, p, was defined as the product of the mass times velocity: p=mv. The angular momentum is signified by capital L. Like the linear momentum, it is also a vector. Based on what you already know, L is the product of which two terms?

In addition to its formal definition, the next two study units, AP1 - Angular Momentum and CC1 - Angular Momentum, will illustrate the conservation of angular momentum using intuitive examples we know from the playground.

You might find these additional video lectures on the rotational motion useful: Khan Academy: Torque and Angular Momentum.

Here are two illustrative simulations on rotational motion PhET - Revolution, Torque.

Gravity

So far in this chapter, we covered the fundamental aspects of motion. You are now in a position to describe the motion of quite a big range of situations. In the next two units, we want to focus on one unique force and one type of motion which are fundamental to physics as a whole.

We start with the force of gravity and a thought experiment: Suppose we let a bowling ball and a feather fall from a height of about 20 meters above the surface of the earth. Is it possible that the feather would reach the ground before the ball? Share your thoughts and find out more in the Classroom Discussion: Gravity.

We have already encountered gravity at the beginning of this chapter when we described the motion of a free falling object. In its most generic description, given by the general theory of relativity, gravity is not a force. However, in many cases, it can nevertheless be approximated as a force operating between two objects. This is valid for all the situations that we study in this chapter. This unit, AP1 - Gravitation, will introduce you to Newton's law of universal gravitation and some of its consequences.

You might want to have a look at the Khan Academy - Gravitation videos to complement what you learned in this unit.

Feel free to check out the PhET Gravity Force Lab simulation to have a little practice on top.

Harmonic Oscillation

After becoming familiar with one of the two fundamental forces of nature - the second one, electromagnetic force, will be explored in the next chapter - this study unit, AP1 - Harmonic Motion, will introduce you to a very important type of motion we call **harmonic oscillation**. This model has proven to be very helpful in describing the motion of a large variety of systems from a playground swing to the motion of atoms in a crystal.

At this point, it is important to clarify the definition of **oscillation and vibration**. You might see both terms in different resources explaining the same phenomena from the perspective of mechanics. ***Oscillation*** is the repetitive variation of some measure about a central value or between two or more different states in time. The term ***vibration*** is used precisely to describe the oscillation in mechanical systems and that is why this subject is handled under the term vibration in some resources for mechanics.

If you want to learn a bit more about harmonic oscillation you can go over the video lectures of Khan Academy - Simple Harmonic Motion.

Here are two interactive models of various harmonic oscillations: an interactive model of a pendulum from PhET - Pendulum Lab, an interactive illustration of damped and undamped oscillations from GeoGebra.

Chapter Assessment

Before starting with the following assessments, feel free to revise the points that are still not clear to you. The assessment units related to this chapter are composed of two parts:

- Part 1: AP® - Final Exam,
- Part 2: CC1 - Final Exam (Questions 1-26).

Note that some assessments contain subjects which will be dealt with later. In these cases, you should only answer the relevant questions which are mentioned in the brackets.

End of Chapter

Congratulations! You have just finished the first chapter of the module! Within this introductory physics module, we are not discussing the more challenging aspects of classical mechanics, in particular, the procedure that determines the object's position as a function of time by solving differential equations. You will learn and deal with such problems in the Mechanics modules in your Mechanical Engineering studies in the future.

Before you continue to the next chapter, make sure to review points you found difficult. As always, you can consult the relevant chapters in College Physics and also this glossary for the terms and concepts that you struggle with.

Feel free to start a post to share your thoughts and questions about this chapter and see maybe you can answer the questions of your classmates in the Classroom Topic: Motion.

Chapter 2 - Electricity and Magnetism

Unlike the classical mechanics theory from the first chapter, the construction of the physical theory of electricity and magnetism is relatively new. This is mostly due to the fact that conducting experiments in these fields required an advanced technology. The most general **theory of electromagnetism** was formulated by James Clerk Maxwell in the 19th century. According to it, electricity and magnetism are not two different things but two different manifestations of the same thing we call the electromagnetic force.

The essential importance of this theory to physics is embedded in the fact that, besides gravity, all known forces are manifestations of the electromagnetic force. This is an extremely strong statement, which hints the important role played by electromagnetism in our technological environment and its centrality to engineering. The purpose of this chapter is to introduce you to this fundamental field of physics.

Electromagnetism is composed of the theories of **static electricity**, **moving electricity** and **magnetism**. All these theories will be discussed in four study units: Electrostatics, Electric Circuit, Electromagnetic Induction, Capacitance. These study units combine video lectures from AP® Physics 1 (AP1) and the second of the Challenging Concepts (CC2) courses.

At the end of this chapter you will be able to:

- explain the concepts of charge, electric field and electric potential and the way they relate to each other.
- describe basic modules of direct current (DC) electric circuits and the flow of charge.
- explain the conservation of charge and energy in a DC electric circuit.
- apply the laws for conservation of energy and charge to describe potential difference, charge and current in electric circuits.
- explain the phenomenon of electromagnetic induction.
- analyze the factors that affect the induced electric current and determine the direction of its movement.
- describe capacitance using basic electrical properties and character of materials and analyze the properties of capacitors in simple circuits.

We will follow College Physics - Chapters 18-24 as relevant additional readings for this chapter.

To have some digital experiments in addition to the lectures, we will refer to the collection of interactive simulations on PhET - Electricity, Magnets & Circuits.

Electrostatics

We would like to start our discussion of electromagnetism with the basic concepts of electricity. We should hence introduce the time-independent properties, which constitute what we call **electrostatics**. In this unit, we will discuss and illustrate the electric charge, electric field and electric potential. As you shall soon see, electrostatic properties can be observed by rubbing certain everyday objects together.

Electric Charge

The most basic concept in the theory of electromagnetism is that of charge. It is an inherent property of matter and, as you probably know, has two orientations: positive and negative. Along with energy, momentum and angular momentum, charge (symbolized by the letter q) is one of the four basic conserved properties in physics. In addition to the definition and various illustrations of electric charge, the lecture unit AP1 - Electric Charge, will consider the electric force that operates between two charged objects.

Electric Field

As you followed in the previous lecture, Coulomb's law enables us to calculate the force between two charged objects as a function of the distance between them. The great similarity between Coulomb’s law of electric force and Newton's law of gravity is not a coincidence, as you will see in the following two units.

In electrostatics, the concept of an electric field, symbolized by capital E, is a way of generalizing Coulomb's law. Whereas the latter describes the electric force between two charges, electric field enables us to consider the electric force that a single charge spreads in its environment.

As a function of the electric force, an electric field is also a vector quantity. As seen in the next lecture, CC2: Electrostatic Fields, this makes it easy to calculate the total electric force of several electric fields that affect a single charge.

Electric Potential Energy

In the last chapter, we considered the potential energy of an object in a gravitational field. We saw that the gravitational potential can be defined as the work needed to lift a mass point from the surface of the earth to a certain height. Since gravity is a conservative force, the amount of work needed is independent of the path chosen. Electric potential, which is the potential energy caused by an electric force, functions in very similar manner. It is, however, a bit more complicated.

When we considered a falling object in the first chapter, we were always interested in the mass point's potential difference from one fixed point: the surface of the earth. When considering a charge in an electric field, however, we are interested in the potential difference between two random points. In the following two study units, AP1 - Electric Fields and Potential and CC2: Gravitational and Electric Potentials, you will learn all about it.

You can find some additional video lectures on the subjects of electrostatics in the Khan Academy - Electric Field, Charge, and Potential.

Electric Circuit

The concepts of electric charge, field and potential enable us to describe **electrostatic** situations, i.e. situations in which the charge is stationary. But what actually happens when you turn on the light in your room or switch on your computer is due to the movement of charge from one place to another. In this unit, we want to study the flow of charge in an electric circuit. We will start by introducing the general properties of charge flow in a matter and in several types of electric circuits. In the second part, we shall see how the principle of conservation of energy and charge functions in an electric circuit.

Basics

An **electrical circuit** is a closed loop through which charge flows. For example, when you plug the charger of your computer into a wall outlet, you create such a circuit. In this section, you will learn to describe such phenomena in physical terms. You will encounter new concepts such as current, resistance, conductor, voltage and electric power and will learn about Ohm's law, which relates the potential difference in a circle to the flow of charge. In addition, you will get to apply Kirchhoff's rules, which define the energy conservation principle in electric circuits.

Due to the module's introductory character, the lecture on AP1 - DC Circuits focuses on circuits in which charge flows in one direction. They are called direct current (DC) circuits. In your future studies, you will also learn about other forms of circuits such as alternating current (AC).

Conservation of Charge and Energy

As you saw in the previous unit, energy is conserved within an electric circuit as well. Here, we want to further illustrate and discuss the themes dealt with so far in this chapter, while focusing more explicitly on the conservation of both energy and charge. Next relevant section in your courses, CC1: Conservation of Charge and Energy in Circuits, will go through this topic and give the chance to do some practical exercises.

Additionally in the interactive PhET simulation, DC - Virtual Lab, you can experience a circuit construction by yourself and learn more about the interdependence of all the elements in an electric circuit.

Magnetism and Electromagnetic Induction

Up until now, we discussed the basics of electricity. In this unit we will learn about the interrelations between the electricity and magnetism, which is then called **electromagnetism**. Using illustrative experiments, the study unit CC2: Electromagnetic Induction aims precisely at that. It will first describe the properties of magnetism and its flow. Then it will experimentally show how the change in a magnetic field can make charge flow and vice versa. This phenomenon is referred to as an electromagnetic induction and is described by Faraday's and Lenz's laws, which you will also encounter in this unit.

As a mechanical engineer you wonder how electromagnetism can be used to move objects. Share your ideas in the Classroom Discussion: Electromagnetic Motion.

Capacitance

In the final unit of this chapter, we want to focus on the ability of matter to preserve electric charge and energy. With the term **capacitance**, we refer to the degree to which an object can store charge. The component of an electric circuit in which charge is preserved is called capacitor. The battery of your mobile phone is an example of a capacitor. This basic example shows why capacitors are so important and useful.

Capacitance is formally defined as the charge stored on a capacitor divided by the voltage across that capacitor. In the following study section, CC2: Capacitance, you will learn what factors determine the capacitance in an electric circuit and how to analyze it

You might find the Khan Academy - Circuits with Capacitors video lectures helpful in addition to your course materials.

Chapter Assessment

Time to check how well you understood the subjects of electricity and magnetism. Feel free to watch some video lectures again and solve some more exercises before taking the assessment, which is divided into three parts:

- AP1 - Final Exam (questions 1-11)
- CC1 - Final Exam (questions 31-35)
- CC2 - Final Exam (questions 1-20)

End of Chapter

Way to go! You have completed the second chapter of the Physics Module. Before moving onto exploring the subjects of waves and light, make sure to review the points you found difficult.

A thorough additional resource for the whole chapter and more can be found in the archived online course, AP® Physics 2 - Part 2: Electricity and Magnetism. While you might find some of its materials useful, kindly note that this course is not part of your Physics Module and you do not have to take it.

Feel free to check the exercises with solution strategies throughout the chapters of College Physics and to consult the Additional Resources as well.

Please share your thoughts and questions about this chapter and see if you can help your colleagues in the Classroom Topic: Electricity and Magnetism.

Chapter 3 - Waves and Light

So far in our Physics module, we have discussed the motion of various objects ranging from a skateboard that slides down a slope to an electron in an electric circuit. Despite the huge differences, we considered - very often implicitly - all our objects as a point with a certain mass. As such, we were able to locate them in a coordinate system and make predictions regarding their motion. Specifically, our mathematical equations that enabled these predictions were constructed according to the mass point model.

Why is it scientifically justified to treat objects in such a way? One answer could be that it is very intuitive and corresponds to our everyday experiences. This answer is, however, not scientifically satisfying. A better explanation is that treating both an electron and a skateboard as a point mass enabled us to make precise predictions that were experimentally affirmed over and over again.

The point mass is a fundamental model used in physics. However, not all physical phenomena can be described by it. Can you think about one such phenomenon? In addition to the point mass, another fundamental model used in physics is that of a wave, which we will discuss in the first part of this chapter. Moreover, one of the most path-breaking discoveries of 20th-century physics is that many physical phenomena, such as light and subatomic particles, show both the character of a point mass and the character of a wave.

As the title suggests, this chapter is composed of two main parts: waves and light. In the first part, we illustrate the model of a wave, its basic static and dynamic properties. In the second part, we explore light. We start with the more intuitive characteristic of light as a ray and then we discuss the propagation of light as a wave. Both study units in this chapter combine video lectures from all three courses you have encountered so far in the module.

At the end of this chapter you will be able to:

- describe the basic properties of a wave and differentiate wave types.
- define standing waves and describe their patterns of interference.
- explain sound as a longitudinal wave and characterize hearing.
- analyze image formation through lenses and mirrors.
- describe the propagation of light as a ray and a wave.
- explain the concepts of diffraction and interference and analyze them.

Relevant reading material for this chapter can be found in College Physics: Chapters 16-17 and Chapters 25-27.

Waves

This part of the chapter deals with the physical model of a wave. You encounter numerous kinds of waves in your daily life, from sea waves to those performed by fans in football stadiums. However, trying to think about a simple definition that can describe them all is not so easy as it might seem. In this unit you will define what a wave is, learn about the properties of waves in general and about a particular kind of wave we call a standing wave. You will also explore what happens when two or more waves interact with each other and, in the final part, learn how sound can be described as a wave.

Here are some relevant interactive PhET simulations on Waves and Sound you might want to look at while working your way through this part of the chapter.

Basic Properties

Let's begin with a short thought experiment. You are sitting in a coastal control center and monitoring the sea in an area that has often experienced coastal floods. Think about useful information regarding the sea waves you would like to have, in order to decide whether there is a danger of a flood or not.

In this unit, AP1 - Waves, after formally defining what waves actually are, you will learn about their basic physical properties and on the way in which the interaction between waves can be described.

Standing Waves

In the last part of the previous course unit, you already encountered the phenomenon of standing waves. Now we want to continue this discussion with further illustrations and exercises. Standing waves demonstrate the basics of wave dynamics in a very good manner. Working through this section, CC1 - Standing Waves, try to think about the relation between harmonic oscillation and wave dynamics.

Sound

In this unit we want to focus on the phenomenon of sound, which is best described using the wave model. As a preparatory exercise, think about the following question: Can the sound be seen? Share your thoughts in the first part of the Classroom Discussion: Can You See Sound?.

In this study unit, AP1 - Sound, we want to apply all that we have learned in the chapter so far in order to physically describe the sound as a wave. This unit begins with a general description of sound as a wave. Then it discusses standing sound waves and it ends with an exploration of the Doppler effect. You often experience the latter when a fast moving object, say a car, passes near you.

After completing the study unit, you are ready to deal with the real crazy question: why you can only see some sounds but never hear them? Share your answer in the second part of the Classroom Discussion: Can You See Sound?.

If you need to review what you have learned so far before moving on, feel free to consult the following video lectures from Khan Academy - Mechanical Waves and Sound.

Light

This part of the chapter deals with one of the all-time fascinating objects in the history of physics: Light. Physicists from Aristotle (4th century B.C) through Ibn al-Haytham (11th century), Maxwell (19th century), Einstein (20th century) and to the more recent endeavours in quantum physics have formulated various theories about the nature of light.

Why do we want to discuss light at this point of our module? In the previous chapters, we were introduced to two general ways to think about a physical object: as a particle and as a wave. One reason for light being such a fascinating object is because it shows the properties of both. In particular, it behaves both as a bundle of particles and as an electromagnetic wave. As opposed to mechanical waves, which you encountered in the previous unit, an electromagnetic wave does not need a medium to travel through.

As you might guess, the rigorous physical description of light is complex and it is a subject of more advanced courses. The purpose of this subchapter is to give you a very basic and intuitive introduction to light. In particular, the first part focuses on what is known as **geometric** or **ray optics,** which is the theory that - modelling light as a ray - describes its motion and interaction with other objects. The second part explores the less intuitive wave character of light. Using illustrative experiments, it will demonstrate the similarities between light and mechanical waves you encountered above.

In addition to the relevant reading material in College Physics, you might find the following video lectures by Khan Academy on Ray Optics and Optical Instruments and Electromagnetic Waves and Interference helpful for this subchapter.

Image Formation

Let's start with a very common scene in daily life: You are looking in a mirror. How come your image is being formed in this particular way? What exactly takes place there?

Through exploring the phenomenon of image formation, this unit, CC2 - Mirrors and Lenses, will introduce you to the general concepts of geometrical optics. Our general purpose is to understand the dynamics of light when it propagates as a ray. In particular, we concentrate on light's interaction with mirrors and lenses.

Diffraction and Interference

In the final unit of this section and of the chapter as a whole, we want to discuss more thoroughly the character of light as a wave. Despite the fact that light is an electromagnetic wave, it nevertheless shares many properties of mechanical waves.

Wave diffraction describes what happens when a wave encounters an obstacle. Interference, on the other hand, refers to the interaction of two waves or more. These phenomena of diffraction and interference are further described in the next study unit, CC2 - Diffraction and Interference. The unit will also introduce some path-breaking experiments that established the fundamentals of light's character as a wave.

Water waves will be used as an illustrative example throughout the discussion on diffraction and interference. Nevertheless, you should not forget the fundamental difference between mechanical and electromagnetic waves. Do you still remember what this difference is?

Chapter Assessment

Last part is again the time to assess what you have learned in this chapter. As always, feel free to revise the video lectures and solve some exercises before taking the assessment, which is divided into three parts:

- AP1 - Final Exam (questions 12-17)
- CC1 - Final Exam (questions 27-30)
- CC2 - Final Exam (questions 32-38)

End of Chapter

Congratulations on completing the third chapter of the physics module. It was en**light**ening, wasn't it? You can always go back to lectures you found particularly challenging, work through them again and consult the readings and additional resources.

There is an archived online course relevant for the subchapter about light: AP® Physics 2 - Part 3: Optics and Modern Physics. Similar to the previous example for Electricity and Magnetism, this course is not part of your Physics Module and you do not have to take it. However, the materials that are still available there might be useful for you.

Do not forget to check the questions and comments posted by your fellow students, share your thoughts and ask your own questions about the chapter in the Classroom Topic: Waves and Light.

Chapter 4 - Fluids and Thermodynamics

In physics, as in many other fields, there are numerous ways of grouping different examples together in a common perspective. In the previous chapter, we saw how the model of a wave enables us to group together light and fans in a football stadium. One can also group things together in relation to their form and particularly whether this form changes or not under the effect of a certain force. In the chapter on motion, we discussed the dynamics of objects that do not change their form under the effect of a force. We call such objects solids. In this chapter, we want to explore the dynamics of objects that change their form once affected by a force. These objects are grouped under the category of **fluids** and include, among others, liquids and gases.

The basic characteristic of fluids in terms of dynamics is their flow and it will be the focus of the first part of this chapter. In the second part, we will explore the dynamics of heat**,** a field which is called thermodynamics. After introducing several fundamental concepts, such as temperature, we will explore the relation between heat and energy in gases. In particular, we will study how energy moves in the form of heat and how it can be turned into work.

After completing this chapter you will be able to:

- describe the pressure exerted by fluids on their containers.
- explain how the speed of the fluids changes as they move.
- define the force of buoyancy and calculate it for objects that are partially or completely immersed in fluids.
- state the Bernoulli equation and explain the conservation of energy in fluids.
- define temperature and state how it can be measured in terms of pressure and volume.
- describe the ideal gas model and its limitations, and state the ideal gas law.
- explain the two laws of thermodynamics and define entropy.
- describe the four main thermal processes of energy transfer between a system and its environment and analyze their graphical representation.

Reading material for this chapter can be found in College Physics - Chapter 11-15. As usual, at the end of each study unit, you will find a link to relevant resources. Feel free to check the Additional Resources section for exploring more on your own.

Fluids

In this first part of the chapter, we want to study the basic static and dynamic properties of incompressible fluids. We are interested in the same questions and problems that we posed in the first chapter, but this time regarding incompressible fluids.

As you will notice, fluid mechanics play an important role in mechanical engineering. In addition, it is a subfield of the more general continuum mechanics that you will encounter as you proceed with your mechanical engineering studies.

This part is divided into four units. In the first one, we will discuss properties of static fluids and in particular the concept of pressure. Based on that, we will then in the second unit explore the interaction of solid objects with fluids and in particular the force that fluids exert on objects that are submerged in them. In the last two units we will study the basic dynamics of fluids by introducing two fundamental constant magnitudes. Specifically, in unit three you will learn about one such constant magnitude of flow given by the so-called continuity relation. In the last unit, we will discuss the Bernoulli's principle which is the equivalent of energy conservation you saw in chapter one.

The video lecture series of Khan Academy - Fluids is a good additional resource to consult with, as you work your way through the Fluids section.

Pressure in Static Fluids

Pressure is one of the most basic concepts in the study of fluids. Formally, the pressure is defined as the ratio between a force and the perpendicular area upon which it is applied. In this unit, CC2 - Pressure in Static Fluids, we want to discuss and illustrate the concept of pressure. In particular, we want to understand how pressure is distributed in a static fluid.

Buoyancy

As you have just learned, the concept of pressure enables us to use the notion of force in the context of fluids. In the previous unit, we discussed forces affecting fluids. To complete this discussion, we will consider in this unit, CC2 - Buoyancy, how fluids exert a force on objects that are immersed in them.

Think, for example, about the last time you went to a swimming pool and tried to dive under the water and touch the button. You had to fight against a force that was pushing you up, remember? This force is called buoyancy and is the subject of this unit, which will also end our discussion on static fluids.

In addition to trying it out in a swimming pool or the sea on your own, you can also experience buoyancy through the interactive simulation PhET - Buoyancy.

Up for a real challenge about buoyancy? Check out the Classroom Discussion: Buoyancy and see if you can explain the experiment that is shown there. You can also try it by yourself.

Continuity Relation

We are now ready to move forward and study some fluid dynamics. When we considered the flow of charge in an electric circuit, we used the fact that matter is made out of atoms. The flow of charge was the motion of countably many charged particles. In fluid dynamics, on the other hand, we consider flow without any reference to the atomic structure of the fluid. Instead, we use the property that fluids are continuous, that is cannot be decomposed into countably many basic elements.

In this unit, CC2 - Continuity Relation, we will explore fluid dynamics and see how the continuity relation can provide us with a constant magnitude of a flow in terms of its speed and the cross-sectional area along its path.

Bernoulli's Principle

As with all other subjects that were discussed in this module so far, the conservation of energy also holds in fluid dynamics. In this study unit, CC2 - Bernoulli's Principle, we will introduce the relevant concepts that enable us to use energy conservation in fluids. As you might expect, these concepts are similar to the kinetic and potential energy we discussed in the first chapter. More specifically, by exploring the forces that make a fluid change its speed and the change of pressure within a fluid due to gravity, we will formulate a magnitude which is constant at any point throughout the fluid. This magnitude is known as the Bernoulli principle.

Before moving to the next part of the chapter, following exercises from the CC2 - Pressure, Force, and Flow in Fluids can help you to assess how well you understood the subject of fluids.

Thermodynamics

In this second part, we study the thermodynamics, which is described as the dynamics of heat, "*thermo*" being the Greek word for heat. Work producing heat is an intuitive fact known to many organisms. For example, remember rubbing your hands to each other to warm them in cold weather.

The fact that heat can produce work, however, is not at all self-evident. This was one of the most fundamental discoveries that powered the industrial revolution at the beginning of the 19th century. Back then, the central problem was maximizing the efficiency of the newly invented steam engine. The development in thermodynamics is an excellent example of how concrete engineering problems led to discoveries and construction of new scientific theories.

This subchapter is divided into four units. In the first, we discuss two fundamental concepts of thermodynamics: temperature and ideal gas. In the second unit, you will learn about the four basic thermal processes and the first law of thermodynamics. In particular, by analyzing their graphical representation, you will learn to describe thermal processes both qualitatively and quantitatively. In the third and last unit, you will learn about entropy and the second law of thermodynamics.

Luckily enough thermodynamics can be made very intuitive through practice. Hence, it is hence recommended to explore interactive simulations on PhET - Heat & Thermo. Feel free to use them throughout this subchapter.

In addition, you can also use the Khan Academy - Thermodynamics video lectures for this subchapter.

Temperature and Gas Laws

The central purpose here is to describe the transfer of energy as heat via the medium as gas. Thus in order to explore this problem, we first must construct two essential elements:

First, we require a generic measurement of heat, which we will call temperature. In order to define the measure of temperature, we must find a way to express heat in terms of other basic physical units. As you see in this unit, CC2 - Introduction to Gas Law and Measuring Absolute Zero, we will use pressure and volume.

Second, we require a generic model of gases that can be used as an approximation of a large variety of gases that we actually know. This model is called **ideal gas**. The ideal gas law is very useful in thermodynamics for describing various states and dynamics of gases.

Basic Thermal Processes

The relation between volume, pressure and temperature is central to thermodynamics. We have seen it already when we defined temperature in terms of pressure and volume. In this section, we want to study the four most fundamental thermal processes. In particular, we want to understand how changes in volume, pressure and temperature relate to one another.

In the first unit, CC2 - The Four Thermal Processes & the First Law of Thermodynamics, we will define and illustrate the isobaric, isothermal, adiabatic and isovolumetric processes. In addition, we will introduce the first law of thermodynamics, where adiabatic expansion is a special case.

Now that we are acquainted with the four basic thermal process types, we want to learn how to use them when analyzing concrete processes. For this purpose, it is very helpful to consider the graphical representation of a given process. For thermal processes, it is very helpful to construct these representations in terms of a pressure vs. volume diagram. This is the focus of the following study unit, CC2 - Reading a Pressure vs. Volume Diagram.

Entropy and the Second Law of Thermodynamics

Thermodynamics has four major laws. The zeroth law is so intuitive that it is often left out. It states that thermal equilibrium is a transitive property. That means, if two systems are each in a state of thermal equilibrium with a third one then they are also in thermal equilibrium with each other. This law was implicitly used when we defined temperature.

The first law, which you encountered in the previous unit, is the thermodynamic version of the principle of energy conservation. Intuitively speaking, the second law of thermodynamics deals with the 'direction' of thermal processes or, more generally, with the order of a given system. Did you ever wonder why, for example, heat transfer occurs from higher to lower temperature but never spontaneously the other way around? You will be able to answer this question after completing the lecture CC2 - The Concept of Entropy and the Second Law of Thermodynamics.

Chapter Assessment

After solving the exercises, CC2 - Thermodynamics, for the thermodynamics subchapter, feel free to check the relevant additional exercises from Khan Academy on Thermodynamics and Fluids as a preparation for the final assessment of the chapter. Whenever you feel that you are ready, go ahead and take the final assessment that is comprised of two parts:

- CC2 - Fluids (Questions 26-31)
- CC2 - Thermodynamics (Questions 21-25)

End of Chapter

Way to go! You have finished the fourth chapter of your Physics Module. Feel free to revise challenging topics using the video lectures and the chapter's reading and additional materials.

A comprehensive additional resource for this chapter can be found in the archived online course, AP® Physics 2 - Part 1: Fluids and Thermodynamics. Kindly note that this course is not part of your Physics Module and you do not have to take it, but you can make use of the materials that are still available in it.

Please share your thoughts and questions about Fluids and Thermodynamics in the Classroom Topic: Fluids and Thermodynamics.

Chapter 5 - Atomic Physics

One intuitive way to characterize the difference between classical and modern physics is in terms of the size of the objects they deal with. As you saw in the first chapters, classical physics describe big objects or objects we can experience with our own eyes. Modern physics, on the other hand, deals foremostly with infinitely small objects like subatomic particles, which we can only encounter in the laboratory.

As is evident from its name, atomic physics is the physical branch that studies the atomic structure. In this final chapter of the Physics module, we want to introduce you to one central phenomenon of the atomic structure known as atomic electron transition. This phenomenon refers to a change in the electron's energy level within the atom. While it is an advanced topic for an introductory physics module, essentials of atomic physics and atomic transitions are important for the understanding of two main subjects at this level.

First one is the concept of **light as a particle**, which is a discussion we started earlier in the third chapter of our current Physics Module. In parallel to the establishment of its wave properties, experiments showed that light cannot be explained only as an electromagnetic wave. In some situations, light behaves like a bundle of particles that carry energy. A single light particle is referred to as a photon and unlike classical particles, a photon has no mass. Light's particle character is best observed when one studies its interaction with atoms. Precisely what we shall do in this chapter is to explore the change in an electron’s energy level due to interactions with light photons to illustrate the particle character of light.

Second subject is the **radioactivity**, which is an introduction to the field of nuclear physics and will be dealt with further in the General Chemistry Module. We will have a brief deeper look into the atom, which was once thought as the ultimate substructure of matter, but then found out to have a substructure within called nucleus. We will see that the characteristics of these substructures trigger great level of energy transitions.

At the end of this chapter you will be able to:

- describe the particle characteristics of light and its interaction with atoms.
- explain the energy transitions through the principle of conservation of energy.
- calculate the energy required for electron transitions.
- calculate the wave related properties of emitted and absorbed photons.
- analyze and construct representations of energy transitions.

We will be referring more to external resources in this chapter to establish the essentials of this subject. In addition, the interactive PhET simulation - Models of the Hydrogen Atom might be useful for experimenting both units of this chapter.

While it is an extensive subject that can be handled in different ways, we again suggest following the reading material in College Physics - Chapters 30-31 for this chapter.

Atomic Structure

One of the fascinating systems explored by modern physics is the region at the center of the atom that is referred to as the **atomic nucleus**. Just to get a general orientation regarding its magnitude, if we compare an atom to a football court, then its nucleus has the size of a ball.

Before getting into too many details, you might want to learn more about the important milestones in the research history of the atom. Please have a look at this short article, Discovery of the electron and nucleus, and the video History of Atom. Of particular importance is Rutherford's experiment that led to the actual discovery of the atomic nucleus. This video about the The Discovery of the Atomic Nucleus summarizes Rutherford's experiment and does it in his original laboratory. Isn't it fascinating that what we refer as the atom is actually mostly an empty space?

After becoming familiar with the general historical background, let us learn more about the basic structure of the atomic nucleus. The following video, Khan Academy - Introduction to the atom, discusses the basic components of the nucleus and specifically the electron, proton and neutron. In atomic physics, hydrogen plays a very important role. Unlike other elements, for which we can only make rough approximations, the measurements and predictions regarding hydrogen are very precise. Using hydrogen as an example, the next video, Khan Academy - Atomic number, mass number, and isotopes, will explore some further basic properties like the atomic and mass number and will introduce you to their scientific notation.

By now, you have probably asked yourself the following question: what keeps all the particles of the atom from falling apart? To close our short introduction, this video tutorial on Nuclear Binding Energy discusses the strong force that keeps all the particles of an atom together. We call this force the binding energy of the atom.

Atomic Transitions

After we got acquainted with the structure of the atomic nucleus, it is time to explore it in terms of energy. So far in our discussions on energy, we implicitly assumed that it can take any value. For example, we can have the sum of the kinetic energy and gravitational potential of a moving object take any random value. This is due to the fact that its energy is a function of its velocity, mass and height. Moreover, with any change -no matter how small- in the value of one of the three, the magnitude of the energy changes accordingly. Therefore the energy is mathematically described as continuous.

One of the most important discoveries in the history of physics, made by Max Planck at the beginning of the last century, is that at the atomic level energy can take only certain values**.** In other words, at the atomic level the energy changes in discrete quanta. This is also the meaning of the word quantum in phrases like quantum physics.

If we say that the thermodynamics is the field that connects physics and economy, atomic physics would be then an example of the connection between physics and politics. For example, the production of the atomic bomb was possible through the research in the field of atomic physics in the first half of the 20th century.

Today, after more than a hundred years of research and development of laboratory equipment, quantum physicists have developed rigorous theories that describe the dynamics of the atom. The final study unit of the Physics module, CC2 - Atomic Transitions, discusses one of the fundamental dynamic processes within the atom, where electrons surrounding the nucleus move between energy levels while the total energy is conserved.

Chapter Assessment

Please once more go through the lectures and reading materials quickly and then take the final assessment, CC2 - Final Assessment (questions 41-45).

End of Chapter

Congratulations for completing the last chapter in your Physics module! Looking forward to your future physical journeys?

Please share your thoughts and pose questions regarding this chapter in the Classroom Topic: Atomic Physics.

Concluding Remarks

Physics is the fundamental subject of your engineering studies and naturally you will encounter what you have learned in the Physics Module continuously in the upcoming parts of your study.

The concepts that you learned in the first three chapters on Motion, Oscillations and Waves will appear again in your Mechanics I, Mechanics II and Mechanics III modules and you will learn more about their application in engineering systems.

Electromagnetism subject will be reviewed shortly and then taken to more advanced practical and theoretical levels in your Principles of Electrical Engineering module.

Together with the things you learn in your General Chemistry module, physics will again be the starting point of your Materials Science and Thermodynamics I modules.

It is therefore important to highlight once again that you can always come back to this material for reviewing these fundamental topics and improve your understanding to get through your studies comfortably.

After completing the Physics Module, you can continue with your studies with the next modules in the Introductory Level. If you have not done yet, feel free to check the General Chemistry and Mathematics I - Single Variable Calculus modules, which are both very important for the further parts of your studies.

Do not forget getting in touch with Engineering Department and your fellow classmates in the Mechanical Engineering category of the Forum, in the Google Classroom for Mechanical Engineering Students or in the Google Hangout channel for Mechanical Engineering Students in the rest of your studies.

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