ARPHYMEDES

TEACHERS BOOK

Authors of the Arphymedes: Teachers Book

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INTRODUCTION

The authors have prepared a book for students that includes augmented reality used to deepen their knowledge and give them an insight into experimentation. The concept is based on experiential learning, and stems from the recognition of the learner as a holistic being and the nature as an indivisible whole, where the book for students also enables distance learning and is a reachable source of explanation. Therefore, we wanted to create a functional toolkit, a unit of a book for students and a book for teachers, thus we recommend using them this way. The student should be actively involved in the cognitive processes, AR and hands-on experiments to derive the results, which can be compared with the explanatory part of the text (in the book for students), further completed and corrected. This teaching way leads to creativity, lasting memory, independence, teaching individualization and differentiation, critical thinking and finally, the skills development

ABOUT THE TEACHER' S BOOK

On material for students and the role of the Teacher's Book or Guide

This book is intended to accompany the collection of supplementary and additional materials for teachers, teaching physics to their students. The student resources create a collection of activities that complement, enhance, and enrich the common textbook material used at schools. The elements of Augmented Reality (AR) stand out as a modern approach to teaching, and as an attractive and motivating source for young people. The experimental work stands at the forefront and is linked with the experience of pupils. The basic layout of SB content is spread over two A4 pages, working without boundaries between them (Figure 1).

Figure 1: Layout of the student ́s book content spread over two A4 pages

The specific picture material (in the form of sketches) has also additional message beyond the basic message, as they contain the AR triggers. The material users will need a smart phone or a tablet with a camera and the downloaded application (Figure 2).

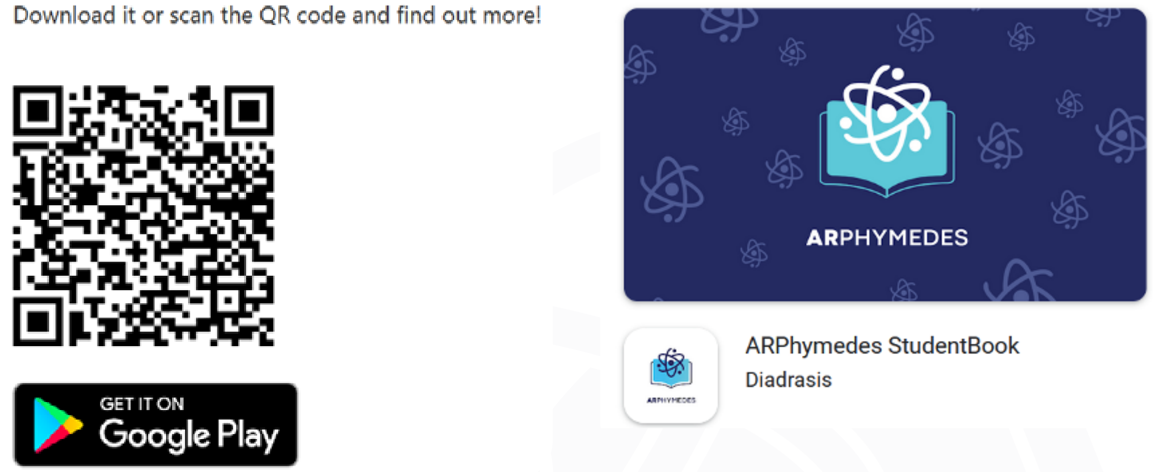

Figure 2: QR code (left) for downloading the application (right).

Once the lens captures the image (trigger), contained in the printed or e-version of the materials, it starts to perform augmented reality. In this context, ta recording of performed experiment, an experiment in virtual reality or an animation can be observed (Figure 3).

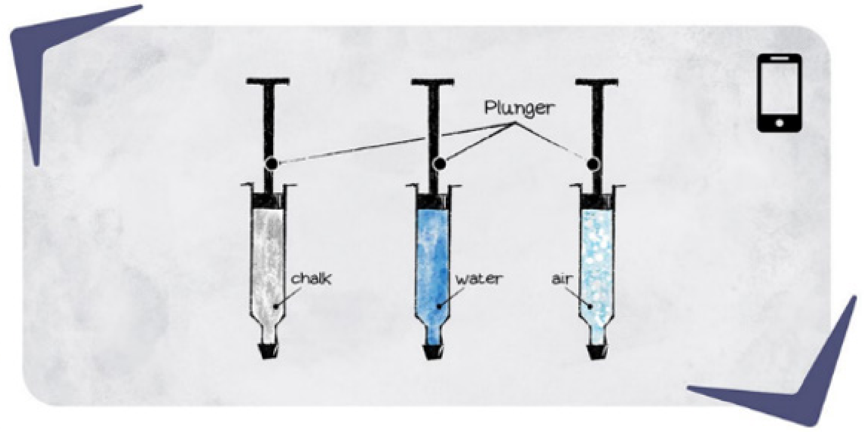

Figure 3: An example of an image that is also a "trigger" for the animation.

The design of the student resource is not based on a sequenced content to follow the curriculum, but as the additional material to enrich the classroom or independent work of students. Calculations and equations are mostly omitted from the student materials, as the material is intended to enhance the understanding of the concepts and phenomena in physics, and to promote higher cognitive levels of thinking and understanding. The Teacher's Book provides and suggests specific places where the teacher can place calculations, and introduce them step-by-step with explanations, clarifications, and suggestions. The explanations and guidance in the student material are bound with student's everyday situations and experience, which lead to the implementation of activities, presented in different ways. The historical perspective and the link to the science development offer opportunities for a specific approach to learning physics. Examples of technical solutions (products, devices, machines, etc.) based on physics concepts and content are included. The amount of text is not large, so the Teacher's Book contains suggestions, clues, questions, reinforcement of the student material with additional explanations, technical materials, calculations, etc.

The following chapters of the Teacher's Book coincide with the chapters of the student´s book, where the following chapters are included:

- What is physics
- Mechanics - Dynamics
- Mechanics - Kinematics
- Fluid mechanics
- Energy, power, work.

The title of each chapter (both in the student´s material as well as in the teacher's book) is the starting point for the chosen physics topic discussion (Figure 4).

Figure 4: Chapter covers in student and teacher's book

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Arphy, the main character of the student material, features in specific situations that raises questions related to the content, and guides the pupils across time, important events, and introduces them to the selected physics concepts. The teacher should point out the specific features, indicate open questions or tasks, and during the activities lead students to discover and seek answers. The teacher can play a special role in providing the students with the context of science development by telling the stories that reveal the historic times, circumstances and conditions in which scientists described, and explained the phenomena in nature. Often, when learning physical concepts, the insights in the history of science are followed by further steps the students also need to absorb. That is the reason why this Teacher's book contains information and interesting stories about famous people who have contributed to the development of science.

Each chapter of the Teacher's book summarizes the learning objectives pursued by the student material as it outlines the misconceptions students often have about each subject and suggests how to overcome them. For each section of the learners´ material, the book provides suggestions for activities, discussion prompts, questions for learners, project tasks with guidance, and materials to deepen their knowledge.

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CHAPTER 1

WHAT IS PHYSICS

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WHAT IS PHYSICS?

The name of physics comes from ancient Greece, where in ancient Greek the word meant the study of nature. Physics is the fundamental branch of natural science that deals with matter and energy and their mutual influence. Physics describes the universe from the smallest to the largest imaginable dimensions. It describes processes at the sub-microscopic level as well as at the level of the whole universe size. Physics is connected to other branches of science in which the research continues to raise new questions leading to further research. During the history, the physics theories were changed, extended, and combined. For example, Newton unified the mechanics of space bodies and the mechanics of bodies on earth as well as in the laboratory; Oersted unified electricity and magnetism, Maxwell electricity and optics, quantum mechanics combines and unifies mechanics and chemistry.
Thus, in physics, knowledge has been built, and we know that new findings will change or upgrade the current knowledge, and existing theories that describes our observations and measurements in nature.

Operational objectives (learning outcomes).
In the chapter What is Physics, students gain insight into what physics describes, how is physics embedded in different branches of science, and what areas of our lives it affects. They learn what tools to use to describe the phenomena and how theorems, laws, equations, and units are expressed and written in physics.

Students will:

- discover the importance of experimentation in learning and verifying physical laws.
- learn the importance of combining experimental knowledge with theoretical, analytical, and synthetic thinking.
- learn about the indivisibility of the measurement number and unit, and that the values of physical quantities as their product must always be written.
- use texts with physical content, professional literature, e-materials, professional websites, and other resources to acquire knowledge and data.
- recognize the importance and indispensability of physical knowledge for technological development and mastery of nature.
- learn to evaluate the scientific achievements of physics, their impact on the changed living conditions and the progress of society, and general culture.
- learn about the historical and social effects on the physics knowledge development.
- develop an awareness of the inseparable relationship between the individual, society, and environment.
- think critically about the use of scientific achievements to be aware of their shared responsibility for the existence of life on Earth.
- describe the phenomena studied by physics and the physics application in

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everyday life, science, technology, and medicine.

- learn and apply following methods and forms of work in physics: observing, planning, measuring, experimenting, drawing conclusions, interpreting measurements and experimental results.
- define the terms: physical quantity, physical unit and measuring device.
- recognize selected physical quantities.
- measure length or time independently, calculate the average value and estimate the measurement error (E).
- adopt prefixes, recognize conversions between units of measurement and used prefixes.
- compare the dimensions of the atom and other microscopic particles with the dimensions in the universe (Bajc et al., 2011).

Chapter cover

The title of the chapter suggests that physics is interweaving the theoretical and experimental branches of physics. The equation, written on the blackboard, is the mathematical description of a physical property. We can talk to students about symbols, units, and their notation. The Greek alphabet can be presented, as it is very well represented in physics, since many physical symbols contain Greek letters. Conversion of already known quantities and units can be repeated and attention could be drawn to their appropriate notation. The discussion can lead into standard units and their importance for proper communication in science.

The cover page shows three measuring devices that students have already known: Thermometer, Ruler, Stopwatch. We can introduce students with measuring devices and tools, measurement procedures, and agree on the rules to follow, when measurements are performed. At the same time, we can familiarize the students with the laboratory equipment, the laboratory rules and safe equipment use as well as keeping their own safety.

Closer look at the cover page can derive a possibility to plan and perform an experiment. Teacher can ask students to use measurements to prove which spoon is better for stirring water, while monitoring the temperature of water over time. Students will already know the answer, but we can challenge them to prove their assumption with measurements. We remind students

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Teachers Book
ARphymedes

about the procedure when measuring temperature during heating, as it is important to stir the water, to measure time and temperature systematically, and to record the measurements in a table prepared in advance. At the end, we interpret the measurements with the students and answer the research question. This example that can be presented as a prime example of physical experimentation and research in science. Throughout the history, although scientists have predicted outcomes, but the assumptions are to be confirmed only through systematic measurements. For that purpose, they use measuring tools and instruments that must be properly calibrated. Modern research also relies on series of measurements that are interpreted and written down in the form of a mathematical expressions. Mathematics is thus a tool of physics to record, describe and interpret phenomena. The cover of the chapter indicates further work and activities within the chapter, related to the scales of observed systems, as well as the description and interpretation of the phenomena in nature.

Famous scientists

The introductory part of the chapter consists of descriptions of the work and lives of three important people in the history of physics

Aristotle (384-322 BC) lived and worked in the period of ancient Greece, was one of the most important personalities in the development of science in the ancient history. He was a student of Plato and developed a holistic view of the world. He founded his own school, which he called Lyceum. Even today, this term is found in the names of educational institutions around the world. He was a prolific author of books covering various fields such as zoology, botany, poetry, physics, and politics.

Aristotle divided the world into two parts, the world under the Moon and the world beyond the Moon, the first being changeable and impure, and the second unchangeable and divine. According to him, the Earth was the centre of the universe. He tried to describe the motion of the other known bodies in the universe (Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn, and the fixed stars) with spheres. Aristotle's picture of the universe and the world was valid for a very long time, until the 17th century.

Galileo Galilei (1564-1642) with his revolutionary thoughts and works paved the way for the scientific progress of the Renaissance and the Enlightenment. He was born in Pisa, town famous for its leaning tower. He had a noteworthy influence on the development of astronomy, being the first to observe the celestial bodies systematically with binoculars, which he made himself following the Dutch model, and even sharpened the lenses himself. He described the tides and presented a view of the heliocentric system. After the publication of the book "Dialogues", Galileo was put on trial in Rome, as the court, presided

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over by the Pope, made a strict decision. Galileo was threatened with torture, if he did not renounce the "error and heresy about the motion of the Earth." He was sentenced to house arrest and surveillance. Nevertheless, he continued to create and search. He is credited with the famous saying, "And yet it moves," indicating what he believed in even though he had to deny his beliefs to stay alive. He focused his research on the study of the motion of bodies and the motion of free-falling bodies. Although he is often said to have dropped bodies from the Leaning Tower of Pisa, but researchers in the history of physics believe that Galileo Galilei did not do this. He was among the first to carry out systematic experiments, which he planned, carried out thoughtfully, and the results of which he sometimes predicted based on reasoning. Interesting is that he carried out the experiments with the rolling ball down the slope while singing, where the beat of the song was also the time measure. He attached strings to the ramp, and while the ball was rolling, it made a sound (a beat) every time it rolled over the string. While he was singing, he managed to arrange the strings in such a way that there were successive strikes at equal time intervals. In addition to singing, he used his heartbeat to measure the time (Strand, 2003).

The third famous person listed in the student materials is **Albert Einstein (1879 - 1955)**, one of the people who associates with physics. Albert Einstein is not only a physicist who supplemented the laws of physics, but he is an icon and synonym of modern physics in the world. In 1905, he developed the special theory of relativity. In the same year, four papers were published that greatly influenced the development of physics. In these articles, he discussed Brownian motion, the basis of the special theory of relativity, and connected the mass of a body to energy (Strnad, 2003). Einstein who is also credited with the general theory of relativity. During the World War II, he worked in the United States. The contribution of the research group to the development of nuclear physics enabled the development of the atomic bomb. After the tragic event at the end of the World War II, Einstein with many scientists on the project publicly expressed deep regret.

Questions and activities for discussion with students.

Search the web for some famous thinkers of ancient Greece. Find (online) the scientific achievements of Galileo Galilei.

Why do you think Galileo Galilei was a good singer? What is the characteristic of free-falling bodies?

Think of Galileo's attempt to make balls roll down on an incline. How were the strings arranged on the slope space so that he could hear strokes? You can check it out for yourself by doing this experiment.

How can you measure your heart rate? Measure your heart rate at rest and after 20 continuous high jumps in place. Comment on whether heart rate is an accurate measure for measuring time.

What scientists did Albert Einstein work with during the World War II? Where did he work at that time? What achievement was he ashamed of?

What equation is the most famous in connection with Albert Einstein. Find (online) some famous thoughts of Albert Einstein.

Prepare a crossword puzzle with terms that can be associated with Albert Einstein.

In groups, create a quiz about all three famous scientists (Aristotle, Galileo Galilei, and Albert Einstein).

Put famous scientists on the timeline in correct order.

Questions and activities for discussion with students:

The table below (Table 1) shows the list of experiments/animations as they appear in this chapter. It can be helpful to the teacher in organizing the lessons, since there are written accessories and equipment for conducting the experimental work, as presented in the video behind the “trigger”, figures listed in the table.

Table 1: List of triggering images in the chapter What is physics

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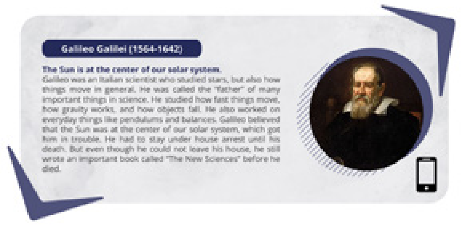
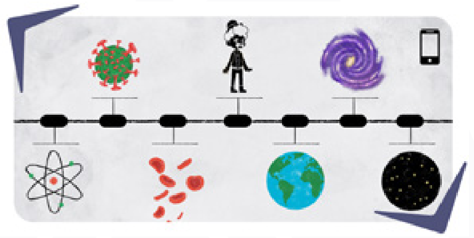
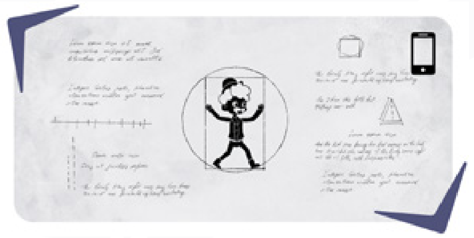
A brief description of the experiment or animation	Figure/Trigger
Animation on Galileo Galilei in Pisa	
Animation on orders of magnitude from the smallest to the dimensions of the universe	
Animation of anecdote about the Cartesian coordinate system	
Animation on scaling	

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Bajc, J. idr. (2011). Učni načrt, Fizika: osnovna šola. Ministrstvo za šolstvo in šport; Zavod RS za šolstvo.

http://www.mss.gov.si/fileadmin/mss.gov.si/pageuploads/podrocje/os/devetletka/predmeti_obvezni/Fizika_obvezni.pdf

Strnad, J. (2003). Razvoj fizike (The development of physics). DZS.

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CHAPTER 2

MECHANICS: KINEMATICS

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Mechanics: Kinematics

What is Mechanics: Kinematics

Mechanics is the branch of physics that describes the motion or rest of bodies. **Kinematics** is a sub-branch of mechanics that describes the motion of bodies in an observed system. In this process the system of observation and the coordinate systems play an important role.
In this chapter, students identify the motion of bodies using animations and deepen their knowledge in dealing with graphical representations of motion.

Operational learning objectives

Students will:
- plan and carry out simple experiments and research, process data, analyse the results of experiments and draw conclusions.
- define the difference between the movement and rest of the observed body in relation to the surroundings.
- describe straight and curved motion.
- distinguish between the concepts of position, distance, displacement, move, path.
- through the animations, learn that speed is the quotient of distance and time (E).
- use the equation to calculate speed.
- describe a uniform and a non-uniform motion.
- distinguish between the average speed and the current speed of the body.
- use the equation to calculate the path.
- recognize a graph that shows the dependence of the path on time, read the data from it, explain it and understand what type of motion it represents (E).
- recognize a graph that shows the dependence of body speed on time, read the data from the graph, explain the graph and understand what type of motion the graph (E) represents.
- recognize a graph that shows the dependence of body acceleration on time, read the data from the graph, explain the graph and understand what type of movement the graph (E) represents.
- calculate unknown quantities using graphs. (Bajc idr., 2011).

Common student misconceptions

In scientific articles we can find many studies that expose and identify the misconceptions of students. Below is a summary of student misconceptions that can be related to this chapter. The list of references accurately reflects the misconceptions listed below. For more details and methods for uncovering misconceptions, see the individual articles listed in the references.

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Within misconceptions, students often
- have difficulties in differentiating between the concepts of velocity and acceleration.
- identify object velocity as a direct indicator of object acceleration.
- believe a constant force keeps an object moving with a constant velocity.
- believe the object will accelerate in the direction of the force that has the largest magnitude.
- share with Aristotle the belief that the speed of a falling body is proportional to its weight.
- believe if there is no force or are some forces exerted on an object, but all forces are cancelled out, the object is always at rest.
- believe a constant force gives a constant speed.
- believe force is not required for objects to fall, since "they always want to go down".
- believe gravity is a kind of impetus acquired by falling objects.
- believe motion is impossible in the absence of a material medium.
- believe two particles have the same speed when they simultaneously occupy the same position, even the two particles were moving with different speeds.
- believe in vt curve the change in direction of the curve represents the change in direction of the object.
- miss the fact that the point where the curve crossed the time axis corresponded to an instantaneous velocity zero.
- express negative velocity on the graph is difficult to think about.
- had difficulty talking about sloped portion of the curve below the time axis.
- have difficulties that are related to an inability to visualize the motion that is depicted in the velocity versus time graph.
- often do not realize that to respond to a question about the position at a particular time, they need to refer to information what is not provided on the v vs t graph.
- fail to distinguish between the position of the object (x) at a particular instant and its displacement (Δx) during a time interval.
- fail to associate the average velocity they with the instantaneous velocity at the middle of time interval.
- often calculate velocities from their measurements of position and time, plot the points, and connect them in a zigzag line.
- have trouble separating the shape of a graph from the path of the actual motion in the converse situation of going from a graphical representation to a laboratory situation.
- often cannot translate the actual physical even into a correct representation on a velocity versus time graph, when a negative velocity is involved, as must be the case when a moving object reverse direction.
- believe when two object reach the same position they must have the same speed.

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- associate being ahead with being faster.
- frequently do not relate their intuition of how fast an object is going to the ratio of the distance travelled to the elapsed time to the idea of velocity at an instant.

Chapter cover
The chapter cover provides a starting point for the conversation. It shows a person on a train sitting in a train. The train moves while Arphy stands outside. The question addressed by the person in the train is: "Who is moving?" (Figure 1).

Figure 1: Cover page of a chapter Kinematics

The teacher should direct the conversation to the importance of the observed system. They should describe who is moving in each observed system. In the landscape system where Arphy is standing, the train and the boy in it are moving, but in the train system, the boy is standing still.

The teacher should review with his students the basic concepts of motion, such as:

- the motion of the observed body,
- the distinction between straight and curved motion,
- the distinction between uniform and non-uniform motion.

By citing examples from everyday life or by recognizing photographs of motion, students can define an individual concept. At this point, the teacher can prepare a simple didactic game in which students look for pairs. For example, a pair represents a card with a picture and a card with a term (Figure 2).

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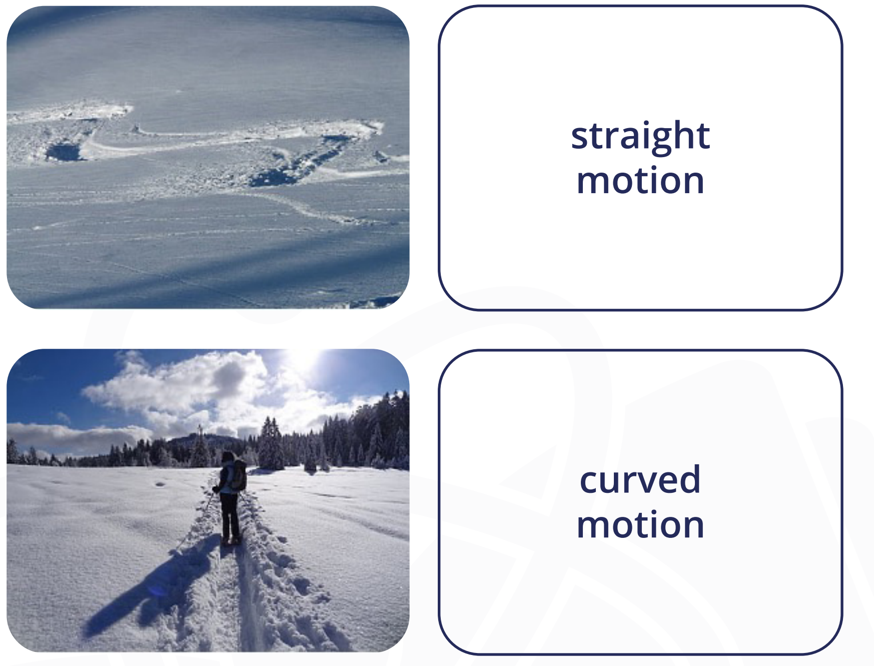
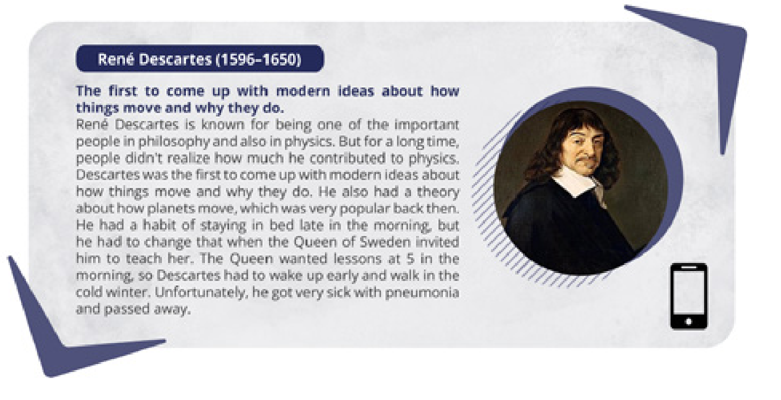


Figure 2: An example of cards for a didactic game. (Image source: https://www.hippopx.com)

Famous scientists
While reading the text, students will learn about three important people: **Nicole Oresme, Rene Descartes**, and **Andre-Marie Ampere**. The teacher develops a conversation with students about their lives, the times in which they worked, and the importance of their work to science. In his work, Rene Descartes devoted a great deal of attention to the Cartesian coordinate system and its application. Even today, the coordinate system is a mathematical tool and the basis for describing motion. The figure below is a trigger for animation on Rene Descartes and his achievements.


René Descartes (1596-1650)

The first to come up with modern ideas about how things move and why they do.
René Descartes is known for being one of the important people in philosophy and also in physics. But for a long time, people didn't realize how much he contributed to physics. Descartes was the first to come up with modern ideas about how things move and why they do. He also had a theory about how planets move, which was very popular back then. He had a habit of staying in bed late in the morning, but he had to change that when the Queen of Sweden invited him to teach her. The Queen wanted lessons at 5 in the morning, so Descartes had to wake up early and walk in the cold winter. Unfortunately, he got very sick with pneumonia and passed away.

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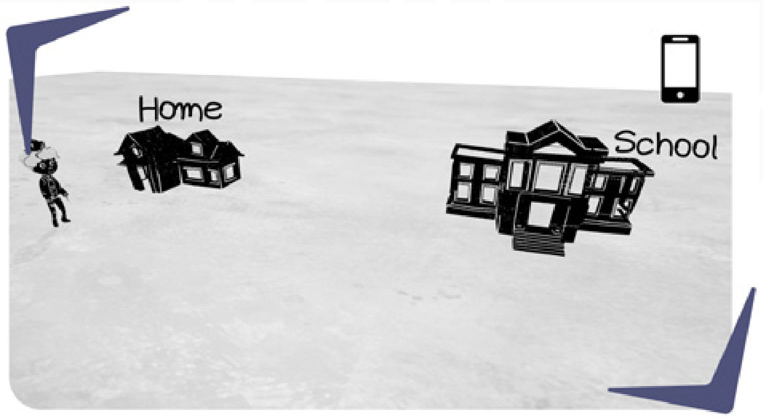
Andre-Marie Ampere is the person after whom the unit for electric current is named. At first glance, it seems odd that it is in this chapter. After students read the text, we can encourage them to search for answers on the Internet or in pre-prepared materials and texts. The following questions and assignments may also be helpful.

Whose work was Oresme criticizing?
Why do you think the description of Oresme's life is in this chapter? For what quote is Rene Descartes best known?
How do you represent the Cartesian coordinate system? How do you label the axes? (Student draws on the board).
Maybe someone knows what the unit for electric current is called?

Find out about Andre-Marie Amper's accomplishments online.

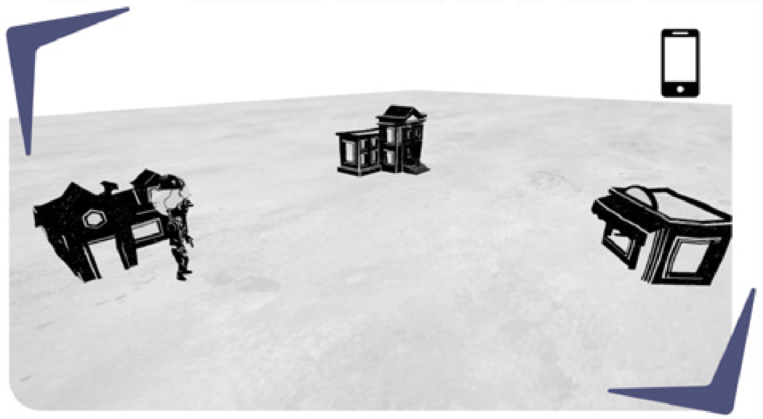
Experiments and animations: position, distance, displacement, path

Through animations, students learn concepts and distinguish between position, distance, and path. When it comes to motion, we use all three terms. In one case, we can travel a long distance, but the displacement from our starting position to our ending position is equal to 0. For example, one such example is when we take a trip from home and return home at the end.
At the first animation, we talk with the students about the concept of position.

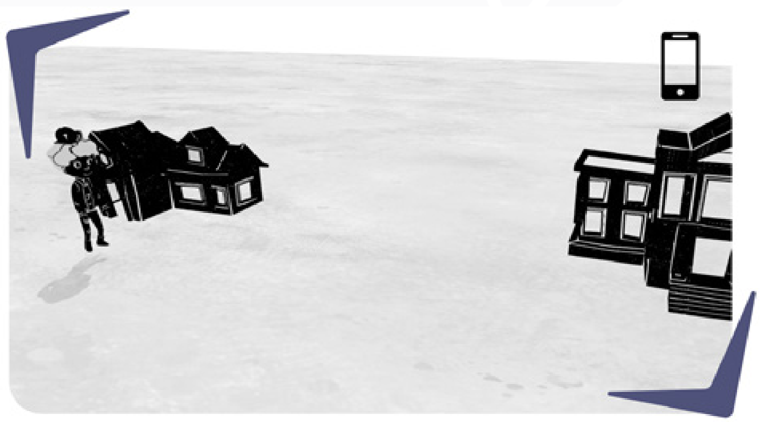


With the second animation, we define the concept of distance from the starting point.

In the third animation, we connect distance, displacement, and path. Arphy ended up in the same place, at the same displacement from home, but in this case, he travelled a longer distance than in the previous animation.



In the last animation, in this set, we can show that even if the path or distance is long, the displacement is equal to 0, since Arphy returns on the same position as he started the journey.



Suggestions for additional activities:

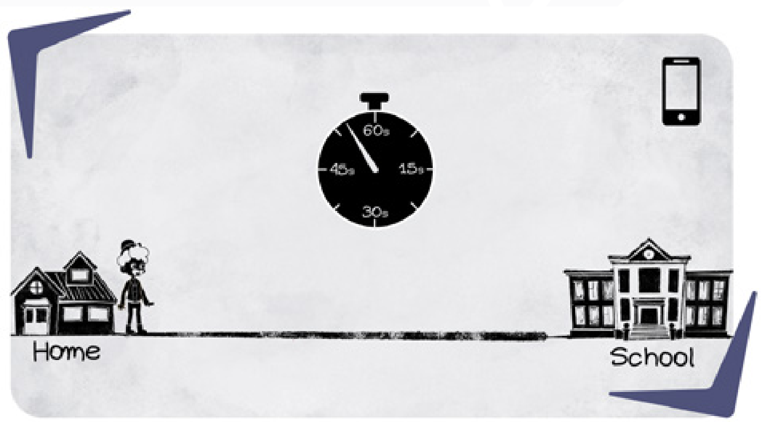
1. You can make a grid (Cartesian coordinate system) on the floor with the students. If the flooring is already in the shape of squares, we will use them. Otherwise, the lines on the floor are made with protective adhesive tape and we write the units on them. We choose some players to change their position in space. The teacher arbitrarily indicates the positions to which the selected students should move. Start with the rule that they can only move in a straight line.

   E.G.: Move from position (1,1) to position (4, 3) and move 5 units. Move from position (4, 3) to any position, keeping in mind, that the distance between the new position must be exactly 3 units. In the game continuation, you can introduce examples of nonlinear motion (e.g., circular motion).

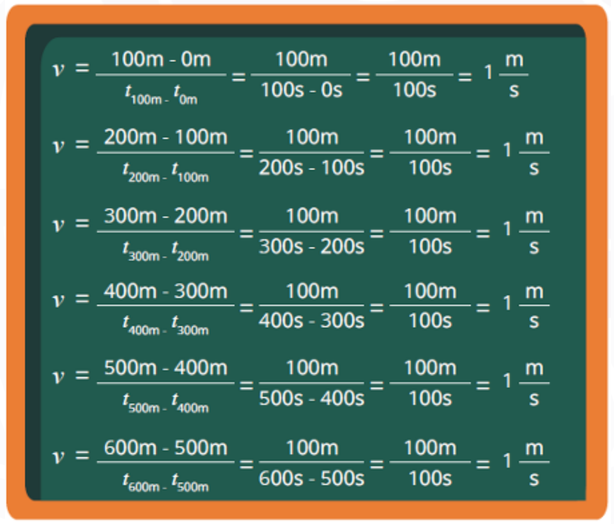
2. Students work in pairs: Each student in a pair is to draw an interesting pattern in the coordinate system that is created with one stroke and consists only of straight lines. Then he writes down the instruction, using the terms position, distance, motion, path. Then he passes the instruction to a classmate to draw the pattern according to his instructions. He compares the product with the original pattern.

Velocity, average velocity

The presented animations did not contain the concept of time yet. It is not possible to see from them how long the journey he took. We know that we can travel the same distance at different times. Students already have this kind of experience, so they can quickly conclude that the one who completes the same distance at the same time is faster and vice versa. With animation, we can introduce the concept of speed as the change of distance in a time interval.



Since it is difficult in the context of the animation to determine the time interval in which Arphy travels 100 m, the teacher should pass this on to the students. From the student materials appears, that a time interval of 100s is used in the calculations on the board. So, in this time interval, Arphy travels 100m. The calculations of the speed in each of the intervals show that the speed was the same, so Arphy was moving in a uniformed motion.



$$v = \frac{100m - 0m}{t_{100m} - t_{0m}} = \frac{100m}{100s - 0s} = \frac{100m}{100s} = 1\,\frac{m}{s}$$

$$v = \frac{200m - 100m}{t_{200m} - t_{100m}} = \frac{100m}{200s - 100s} = \frac{100m}{100s} = 1\,\frac{m}{s}$$

$$v = \frac{300m - 200m}{t_{300m} - t_{200m}} = \frac{100m}{300s - 200s} = \frac{100m}{100s} = 1\,\frac{m}{s}$$

$$v = \frac{400m - 300m}{t_{400m} - t_{300m}} = \frac{100m}{400s - 300s} = \frac{100m}{100s} = 1\,\frac{m}{s}$$

$$v = \frac{500m - 400m}{t_{500m} - t_{400m}} = \frac{100m}{500s - 400s} = \frac{100m}{100s} = 1\,\frac{m}{s}$$

$$v = \frac{600m - 500m}{t_{600m} - t_{500m}} = \frac{100m}{600s - 500s} = \frac{100m}{100s} = 1\,\frac{m}{s}$$

The animation can also be used to define the average speed. Students should find out and estimate how long it took Arphy to walk from home to school. They should also determine the distance travelled. They should enter the selected data into the equation for average speed, calculate the value, and write the unit.

Students are prompted to think about accelerated motion through a conversation. We ask them how Arphy would move if he travelled a longer distance in each successive time interval. Students conclude that his speed should be increasing. In this way, we introduce accelerated motion. If the velocity increases uniformly, i.e., the difference in velocities in a time interval is constant (= the acceleration a is constant), it is then uniformly accelerated motion. The following animation can also be used to introduce uniformly accelerated motion.

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Graphical representations of movement

Using the examples given in this chapter, students consolidate their knowledge of understanding the graph and the calculations of the quantities they can determine as they come to understand the meaning of the area under the graph. At the beginning of this chapter are listed the student misconceptions that are quite common in graphing of motion and are worth considering when dealing with graphing. With the examples collected in the book for students, teachers can supplement the basic examples and materials from classic elementary school textbooks. It is recommended that teachers choose those cases for consideration that correspond to the individual profile of students.

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ARPHYMEDES

CHAPTER 3

MECHANICS: DYNAMICS

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Mechanics: Dynamic

What is Mechanics: Dynamics?

Mechanics is the branch of physics that describes objects in motion or at rest. **Dynamics** is a sub-branch of mechanics that describes the movement of bodies under the influence of forces and torques. In this chapter, students identify bodies at rest and bodies in motion with the help of animations and deepen their knowledge of Newton's laws.

Operational learning objectives

Students will:

- define the concepts of observed body and surroundings.
- realize that forces are the cause of a change in the motion or shape of a body.
- name forces after the bodies that cause them.
- distinguish between forces that act on contact and forces that act at a distance.
- introduce the unit of force newton (N).
- find out that forces of equal magnitude on the selected body cause the same effects.
- determine whether the forces acting on the body are in balance.
- understand that if the forces acting on the body are in balance, the body is at rest or in the uniform motion.
- understand that the forces of friction and air resistance oppose the motion.
- describe the force of friction.
- figure out that bodies interact.
- analyse cases and distinguish the law of interaction (Newton's 3rd law) from the law of equilibrium (Newton's 1st law).
- become familiar with collisions of bodies and the influence of the mass and velocity of bodies on the effects of a collision. (Bajc idr., 2011).

Common student misconceptions

In scientific articles we can find many studies that expose and identify the misconceptions of students. Below is a summary of student misconceptions that can be related to this chapter. The list of references accurately reflects the misconceptions listed below. For more details and methods for uncovering misconceptions, see the individual articles listed in the references.

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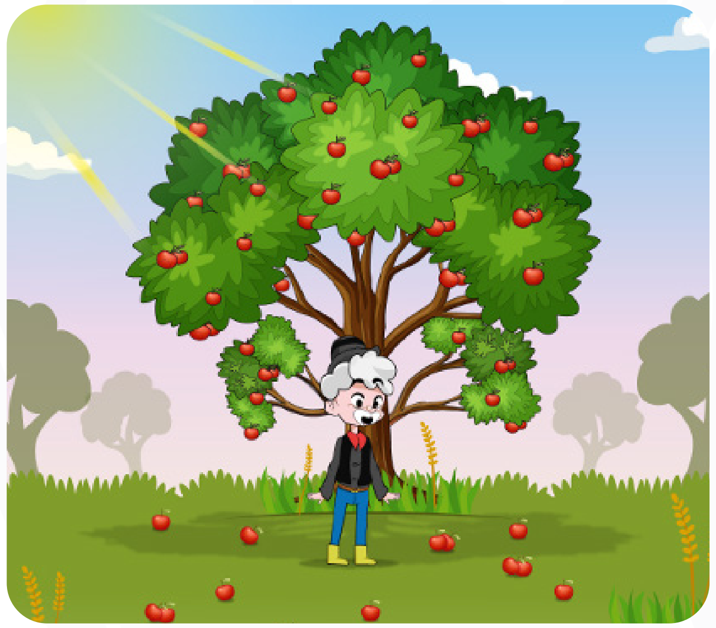
Within misconceptions students often

- believe if there is no force or there are some forces exerted on an object, but all forces are cancelled out, the object is always at rest.
- believe a constant force gives a constant speed.
- believe force is not required for objects to fall, since “they always want to go down”.
- believe gravity is a kind of impetus acquired by falling objects.
- believe motion is impossible in the absence of a material medium.
- misunderstand the concept of force.
- misunderstand Newton's third law.
- believe that force is innate property of an object rather than an interaction between objects.
- believe if an object is at rest, no forces are acting on the object.

Chapter cover



Students should relate the chapter cover to Newton. The anecdote about the falling apple that led Isaac Newton to realize that gravity exists is one of the most famous scientific anecdotes. Newton is said to have hosted a scientist at his home. After lunch, the scientist was supposed to go to the garden under the apple tree, and drink tea. He is said to have been awakened from his deep thoughts by the fall of an apple. He wondered why the t apple always fell vertically downwards. The anecdote is also partially included in the first of the animations, which can be viewed when scanning the image with the portrait of Isaac Newton

Famous scientists

Three scientists are mentioned in this chapter, including **Isaac Newton (1643 - 1727)**, one of the most famous physicists of all time. When the editors of Physics World magazine asked all physicists around the world which five physicists had contributed the most to physics, the result showed that Isaac Newton took second place in terms of number of citations, right after Albert Einstein (Strnad, 2000).

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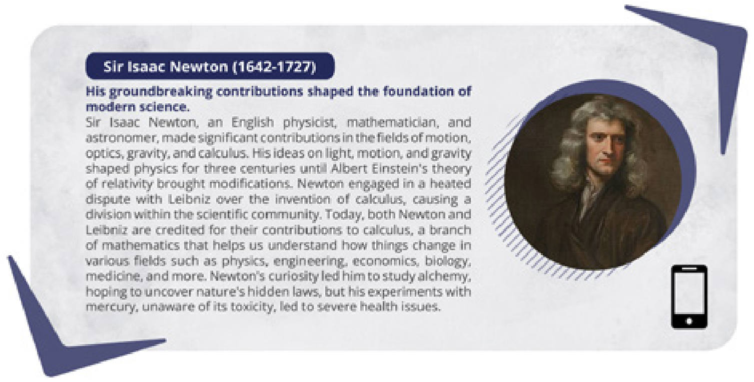
Newton's view on the world and the consistency of his thoughts and writings to the phenomena of nature were extraordinary. He worked in all branches of physics of his time, his greatest contribution to science was in the field of mechanics. He was the first in the history of the development of physics, who established the first internally consistent physical theory, which to some extent is still valid today (Strnad, 2003). The entire population attending elementary school classes is familiar with his laws. An interesting animation, which can be seen after scanning the image below, shows that Newton recognised that a force (gravitational force) must act between two bodies. He also realised that the same force is at play when we talk about orbiting the Sun as when we describe an apple falling to the ground.



In addition to the famous Newton, **Christiaan Huygens (1629 - 1695)** and **Gottfried Wilhelm Leibnitz (1646-1716)** are also presented in the materials for students. Huygens was interested in astronomy, and therefore built a telescope based on his own idea, and micrometre to measure very small angles between stars. He paid special attention to time measurement because he was aware that it was extremely important in physics. He invented pendulum clock, and applied for a patent for it. He also dealt with oscillations and pendulums. He wrote down his theorems based on his measurements. He did important work in the field of collisions, being the first to explain elastic and inelastic collisions.
Leibnitz argued with Newton about who was the first to discover the infinitesimal calculus and who was the plagiarist. The Royal Society formed a commission that decided this question and gave preference to Newton. The dispute between the supporters of one side and the other did not subside for a long time. Today we credit them with having done the work independently (Strnad, 2003).

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Questions for discussion and work with students

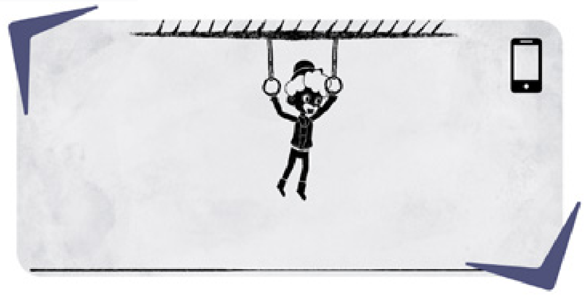
- *Read the entries in the student materials about the lives and work of Huygens and Leibnitz.*
- *What is the most famous book written by Isaac Newton?*
- *What is plagiarism?*
- *How are other authors' sources and ideas cited in scientific circles?*
- *Prepare a short note about the works of Newton, Huygens, and Leibnitz and refer to the appropriate sources (literature).*
- *Take a lump of soft playdough and throw it so that it lands in the centre of the door leaf when the door is open. What happens to the door and the lump? How do we name such a collision? What can you say about the speed of the door and the playdough lump before and after the impact?*
- *Take the tennis ball and throw it so that it lands in the middle of the door leaf when the door is open. What happens to the door and the tennis ball? How this collision differs from the previous one? What can you say about the speed of the door and the ball before and after the collision?*
- *In pairs, investigate collisions between different balls (pool, foam, rubber, etc.), change the initial speeds, direction of collisions and observe in which directions the balls bounce, and where they stop.*

Animations

The first two animations are designed to get students thinking about how a person feels forces. Both experiments are very easy for students to repeat and reflect on the feelings and forces that affect them.
Suggestions for work during and after watching the animation:

- *Draw accurately to scale the forces acting on Arphy. assume that Arphy has the same weight as you.*
- *What is the sum of the forces acting on Arphy?*
- *Which Newton's law describes these two cases?*

In both cases, the teacher should check how the students have drawn the forces. In both the first and second cases, there are two forces that balance the weight (the normal on each foot and the forces in the hands).



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The third and fourth animations are about thinking about the forces acting on Arphy from another person. Someone acted on Arphy by pushing him aside. In another case, someone pulled Arphy by the arm.

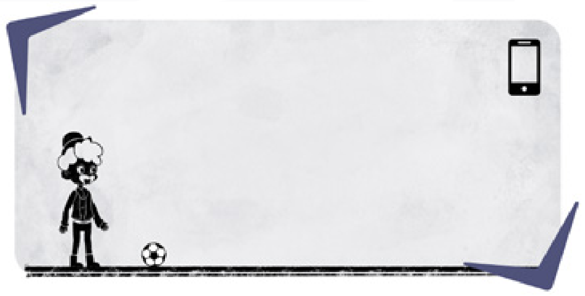
Suggestions for working during and after watching the animation:

- *Watch the animation and draw the forces acting on Arphy in the picture.*
- *Compare the normal forces in the previous two cases and in these two cases. What do you notice? Why is it so?*

Students may notice that Arphy is standing only on one leg in these two examples. So, the normal force on the foot is 2 times greater than in the previous cases when Arphy was standing on both feet.

- *What is the resultant of all forces in each case?*
- *Why does Arphy move and why does he fall?*
- *Which Newton's law describes these two cases?*

Students should watch the fifth animation and consolidate their knowledge of the first example. When the surface on which the ball is rolling changes, it is necessary to introduce the concept of friction, and the effects of friction on the motion of the ball. To summarise, the ball can roll due to the force of friction between the ball and the ground (otherwise it would slide). At the same time, it also stops because of the friction. In this story, we cannot even avoid the air resistance that slows down the ball in the air, and on the ground, except that its influence is much smaller than the influence of friction.



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With the following animation, students will learn about the properties of collisions. At this point teacher with students discuss the characteristics of elastic and inelastic collisions, as well as semi-elastic collisions, like the one shown in the animation. It is a collision between two vehicles of different sizes.

Suggestions for work during and after watching the animation:

- *Students can demonstrate a similar situation with a classroom experiment. Already in the section on famous scientists, the idea was expressed that students should investigate collisions between different spheres. With this animation, it seems reasonable to observe the collision of two different sized balls made of the same material and compare it with the collision in the animation. In the experiment, they can approximate the animation by using two toys - small cars. Have students compare the results of the experiment with the animation.*

They may find that in the animation and in the experiment with toys, the collision is not completely elastic.

- *Using toys or balls, have students further investigate the effects of speed on the effects of collisions. And the effects of the mass of the vehicles at the same speeds on the effects of collisions. They can observe how far the vehicles are from the point of impact after the collision.*

The last animation in this chapter "opens the door" about forces and moments (torques). Using a simple practical example, students can see that it is difficult to push or pull the door when the "moment line" is short, and vice versa, they quickly realize that the handle is placed at the edge of the door for a reason, the longest the "moment line" is, the easiest is to open or close the door.

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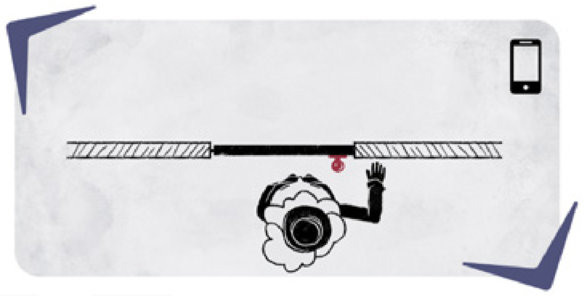

The balance of forces and torques is usually discussed using the example of a swing set or a lever, which is mentioned regarding the cover page of the chapter Work, Power and Energy.

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CHAPTER 4

MECHANICS OF FLUIDS

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MECHANICS OF FLUIDS

What is Mechanics of fluids

Fluids are divided into liquids and gases, which may have different states of matter and shapes. They flow due to pressure differences. Gases are stored in closed containers because they occupy all the space available. Gases are more compressible than liquids. Mechanics of fluids is a special branch of science that describes the properties of fluids when they are at rest and the responses of fluids when various forces act on them. The properties of fluids in motion are described by a branch of science called fluid dynamics.

Operational objectives (learning outcomes)

In the chapter Mechanics of fluids, students will learn about the properties of fluids, hydrostatics, and hydrostatic pressure. They will find details on Archimedes' principle and discuss why some objects float and some sink.
Students will have the opportunity to acquire knowledge and understand the physics facts, ideas, terminology, principles, and concepts. They should understand that scientific concepts passed gradual development through the historical development of science. The important work of key scientists such as ***Pascal, Pythagoras, Archimedes, Torricelli*** is incorporated in the chapter. However, students will be able to apply knowledge through problem solving where data interpretation, description of everyday phenomena and relevant calculations are expected.

Students should be able to
- comprehend that fluids flow.
- understand the term of compressibility and applicate it in everyday life and experiment.
- develop understanding of the term viscosity and temperature dependence of viscosity through "testing viscosity of liquids".
- recognise Blaise Pascal's as a great contributor to development of science.
- understand the Pascal's law.
- use the equation Pressure = Force/Area and describe situations where pressure is inversely proportional to area.
- state that the Pascal (N/m^2) is the standard unit of pressure.
- understand the principle of Hydraulic Jack through experiment with two different size syringes.
- use basic equation for pressure Pressure = Force/Area and work W=F s in an example on hydraulic jack.
- relate the pressure beneath a liquid surface to depth and to density and use the equation Pressure = vertical height x density x acceleration due to gravity.
- apply and connect the equation with well-known Pascal's experiment with

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- barrel and long tube.
- explain the hydrostatic paradox.
- understand the syphon effect and recognise it in Pythagoras's cup (greedy cup).
- make connection between atmospheric pressure and hydrostatic pressure.
- understand that the atmosphere exerts a pressure and that it decreases with increase in height above the Earth's surface.
- understand the term of pressure difference.
- carry out the experiments on pressure difference and connect them to everyday life.
- interpret Archimedes' principle.
- use Archimedes' principle to explain a specific example or situation.
- interpret the concept of buoyancy.
- explain, how various factors determine the force of buoyancy.

Chapter cover

The chapter's cover features the main character Arphy, sitting in a tub, wearing a crown on his head (Figure 1)

Figure 1: Cover page of a chapter Kinematics.

The figure alludes to the famous anecdote on Archimedes, who, while bathing in a tub, is said to be inspired how to solve the riddle of the crown. The king wondered whether his crown was really made of pure gold or whether the goldsmith had tricked him and added another metal to the crown.
Students can be encouraged to reflect on Archimedes and his achievements during the discussion. Below are some suggestions for questions that can be used to guide the discussion.

What does the picture remind you of?
What would you put in a babble?

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Who said the famous "Eureka" exclamation?
What does the anecdote say, what Archimedes discovered while bathing? Have you heard of buoyancy and how would you describe it?
Why does the water spill over the edge of the tub when Arphy lies down in a full tub of water?
How should Arphy be positioned in the bathtub to get the most water out of it?
What can you imagine the title Mechanics of Fluids means? What is mechanics?
Which divisions of substances are you familiar with?
What are fluids? List some examples of liquids.

Famous scientists
The introduction names three historical figures, who have made important contributions to the understanding of mechanics and fluid: **Blaise Pascal, Archimedes and Daniel Bernoulli**.

Would the order of the listed persons stay the same if they were listed chronologically? In what order would they be arranged?
Which of them lived the longest? Search online for famous people who lived in the same period as Pascal, Archimedes, and Bernoulli.
Read short biographies and prepare a role-play depicting the life and work of a selected scientist.
Find(online) additional interesting information about the period, clothing, gadgets and more.
What else has Archimedes been exploring?

Archimedes (287-212 BC) of Syracuse in Sicily summarised, edited, and expanded the knowledge of statics in his time. He was a very important mathematician and physicist of the ancient world. He worked in Alexandria. He will also be discussed in the chapter where we look at working with tools. Archimedes' theorem for the lever was that a symmetrical and symmetrically loaded lever is in equilibrium, and that a force equals to the total weight of all the loads, applied vertically upwards in the axis. Then he asymmetrically combined the loads on one side and the other side and repositioned their anchorage accordingly. He used the concept of the centre of gravity. This research prompted Archimedes to say, "Give me a fixed point and I will lift the Earth" (Strnad, 2003). The chapter Work, power and energy has a chapter cover that suggests this very thought (Figure 2).

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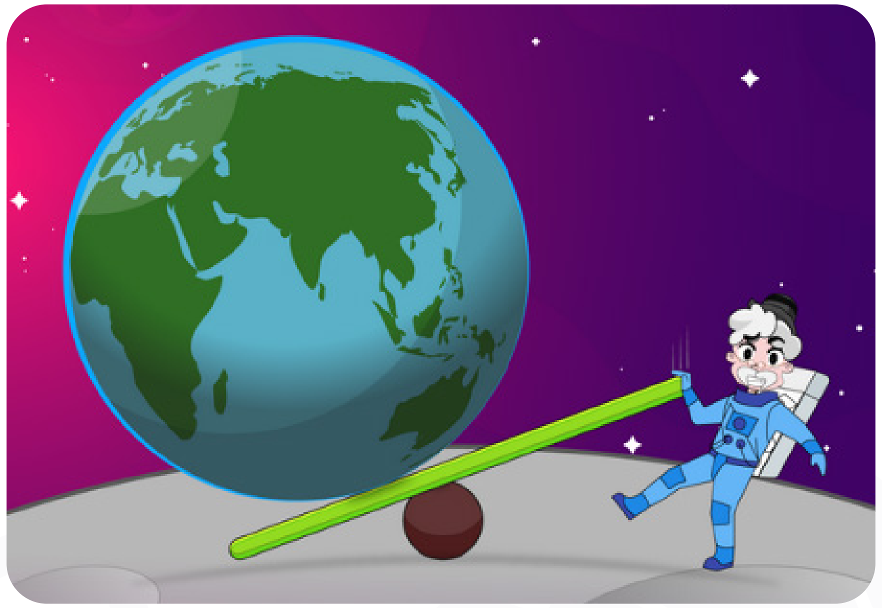

Figure 2: "Give me a fixed point and I will lift the Earth." Cover page of chapter Work, power and energy.

The cover of this chapter includes a crown, which opens the story of King Hieron, who is said to have had a golden crown made for himself. He suspected that the goldsmith had deceived him. Archimedes is said to have realised how to justify his suspicion. The story follows that he weighed the crown and prepared a piece of gold of the same weight, and another piece of silver of the same weight. Then he measured the volume of the crown by immersing it in a bucket of full of water and determining the volume of the spilt water that had flowed out of the bucket. The volume of water, displaced by the crown, is equal to the volume of water displaced by the gold if the crown was made of pure gold. But it turned out that the volume of the crown was greater than the volume of gold and less than the volume of silver. The goldsmith was supposed to have added silver to the gold. Archimedes thus introduced a specific volume and a specific gravity and gave the way of measuring it.

Archimedes also derived the law of buoyancy. Archimedes did not report on the devices he built. He made a water screw to lift water (Figure 3), following the Egyptian example. He made devices for throwing projectiles (called Greek fire) based on a lever, and he gained the trust of his fellow citizens when he used levers to move a ship, although no one had believed that it is possible before.

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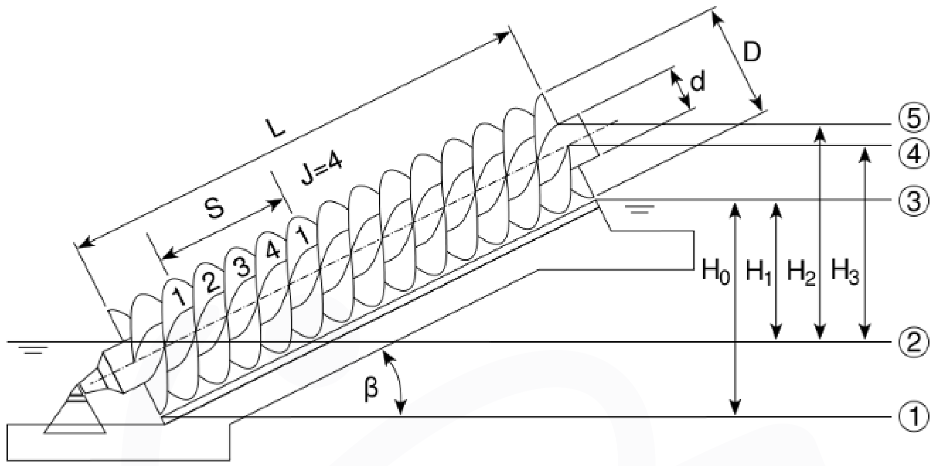

Figure 3: Archimedes' screw was used to raise water. When the screw is turned, the water flows upwards. (Source of figure: https://commons.wikimedia.org/wiki/File:Archimedische_Schraube_komplett.svg)

Blaise Pascal (1623-1662) was the first to explain that pressure exerted anywhere on a fluid in a closed container is transmitted undiminished throughout the fluid and rains perpendicularly on all the walls. He investigated how the pressure in a stationary fluid increase with increasing depth and found that the relationship is linear. Based on the theorem, he conceived of a liquid-liquid press.

Daniel Bernoulli (1700-1782) was the founder of mathematical physics. He worked extensively on the behaviour of gases and the flow of liquids, among other things. He discovered the Bernoulli equation, which holds in a stationary flow of a non-viscous and incompressible fluid and connects two points on a streamline. It describes the law that as the velocity of the fluid flow increases in the horizontal direction, the pressure decreases (Strnad, 2003).

Experiments

Students should carry out the experiments independently or watch the teacher while doing them in front of them. The triggers and accompanying clips or animations should be used instead of a description of the whole procedure. Students should watch the clip, write down the tools they will need, draw a sketch of the experiment and then (if the tools allow) perform the experiment independently. In practice, this type of work should save some time by giving instructions for the experiment, preparing worksheets, etc. Classroom work can be organised as a group work, with students taking turns at stations. At each station are prepared handouts and pictures of "AR triggers". Students can write descriptions, explanations, draw sketches and write questions in the textbook. Alternatively, they can do it in their notebooks. Preferable is that the student keep the structure of experiment procedure as follows:

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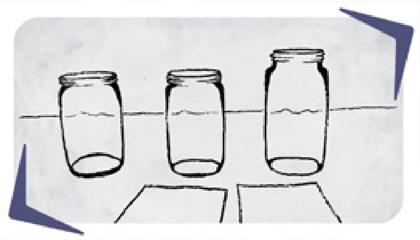
- Write down the title of the experiment.
- Draw a sketch of the experiment.
- Writes down the accessories.
- Describe observations.
- Record findings and results.
- Evaluate the results in a meaningful way.

The first few experiments show students the properties of fluids (fluids can flow, gases take up whole space available, liquids form surfaces, compressibility differs between gases, liquids versus solids, viscosity of fluid).

From the following experiments students realise that the gas can be poured from one glass to another. They can also "see" that gases take up the space (glass) and could be flammable.

The table below (Table 1) shows the list of experiments/animations as they appear in this chapter. It can be helpful to the teacher in organizing the lessons, since there are written accessories and equipment for conducting the experimental work as presented in the video behind the "trigger" figures, listed in the table.

Table 1: List of triggering images in the chapter Mechanics of Fluids with accessories for conducting experiments.

A brief description of the experiment or animation	Figure/Trigger	Accessories
Experiment Gases can flow		Pickling jars, spray, matchbox, cardboard
Experiment Compressibility of air and water		Water/air filled syringe

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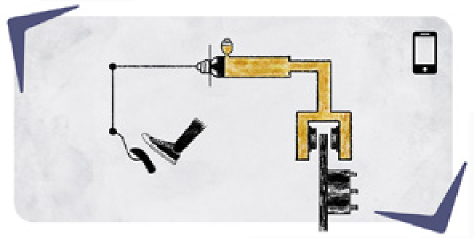
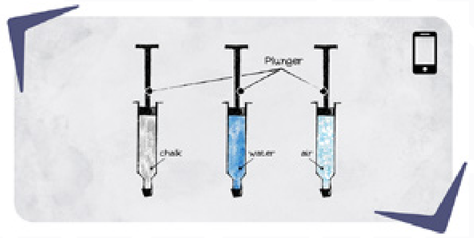
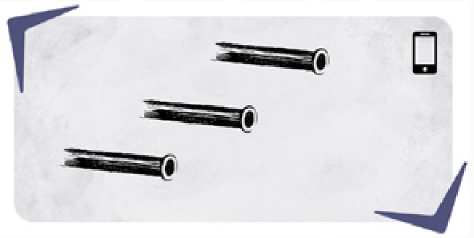
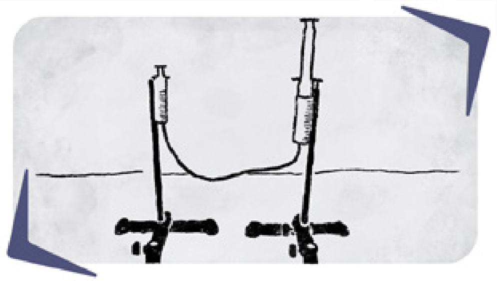
Experiment Extinguishing a candle using carbon dioxide.		Transparent glasses, effervescent tablet (vinegar, baking soda), water, Candle.
Animation Demonstration of how car brakes work.		
Animation Compressibility of chalk, water and air.		
Animation Viscosity of Water, oil and honey.		
Experiment Comparing forces on pistons of a small and a big syringe.		2 syringes of different size filled with water, Stands. connecting tube

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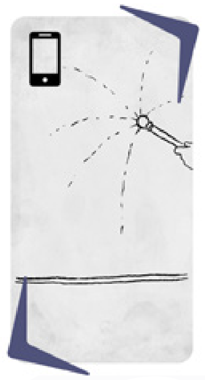
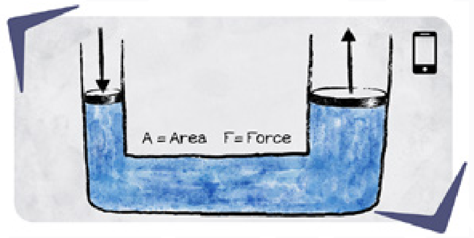
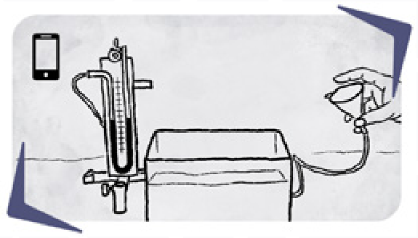
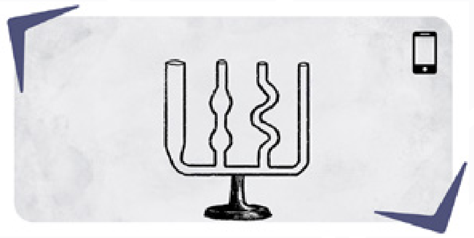
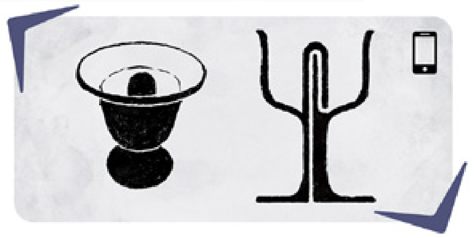
Teachers Book
ARphymedes

Experiment Pascal's Hedgehog: Forces act perpendicular to the surface. The exit jets are perpendicular to the surface of the plastic flask or balloon.		A perforated plastic flask or balloon, large syringe (can also be a water toy for squirting)
Animation Principle behind the hydraulic jack.		
Experiment Hydrostatic pressure is the same in all directions at the same depth.		Manometer or U-shaped tube, coloured water, plastic tube, funnel, balloon
Animation Presenting communicating vessels.		
Animation How a Cup of Justice works?		

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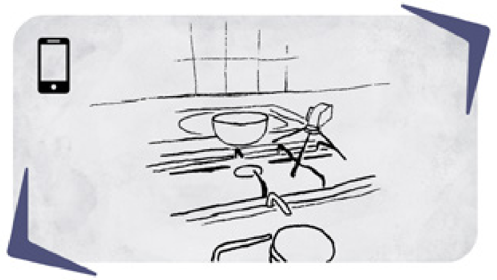
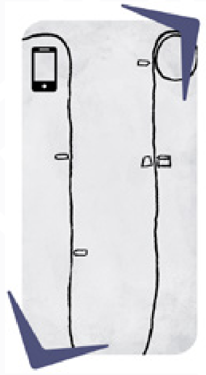
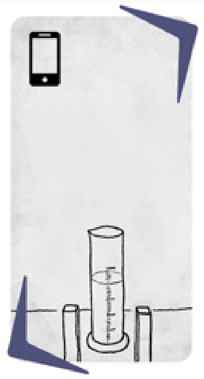
Experiment A difference between air pressure and pressure in the can crushes the can		An empty can. cold water (with ice), tongs for holding a hot can, a gas burner, lighters
Experiment Measuring the mass of air.		Plastic flask with non-return valve, air pump, scale
Experiment Changing the height of the water column by blowing or suction.		Long pipe (more than 2 meters), stand or plate for fixing the U-shaped tube
Experiment Density of an object does not influence buoyancy.		Measuring cylinder filled with water 2 cubes with the same volume made of different materials (different densities) Measuring the buoyant force show the same result when the same proportions of cubes are submerged

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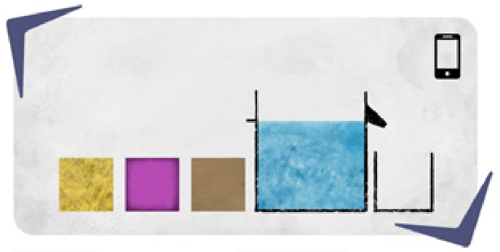
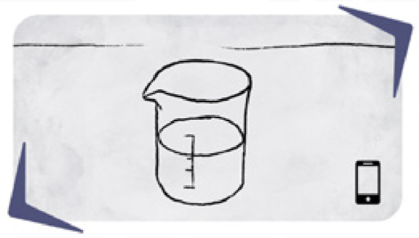
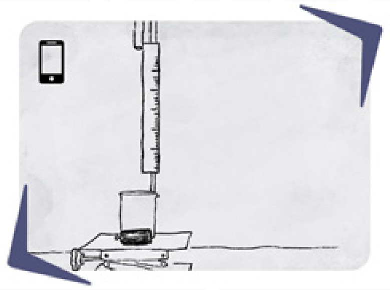
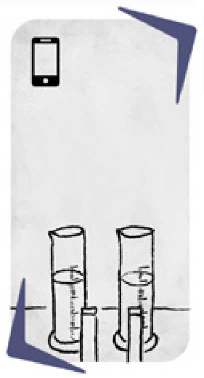
Animation Archimedes' Principle: the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially, is equal to the weight of the fluid that the body displaces.		
Experiment The amount of water does not influence buoyant force on sub-merged object.		A glass, object, spring scale
Experiment Demonstration of Archimedes' bucket.		Archimedes' bucket
Experiment Density of liquid in which the object is submerged, influence buoyancy.		2 measuring cylinders saltwater tap water 2 identical cubes (equal volume) made of different substances (with different densities) For experiment is enough 1 cube. In the video 2 cubes are used for repeating the experiment.

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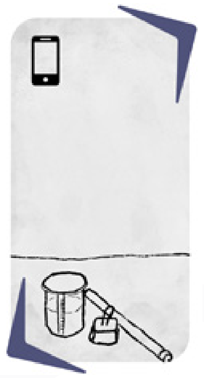
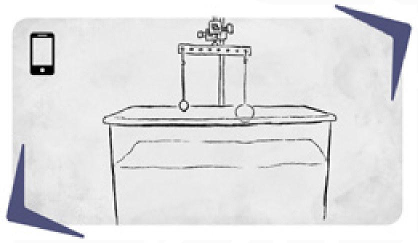
Experiment The buoyant force is independent of shape		A lump of plasticine shaped into a cube and then transformed into a sphere spring scale measuring cylinder water Use the same liquid and submerge objects of same material and volume (plasticine).
Experiment The buoyant force depends on immersed volume and do not depend on the mass of an object.		Spheres with the same mass, different volume crossbar stand, string, larger container of water

The teacher should be autonomous to choose or make order of experiments/animations. The theoretical frameworks, ideas and suggestions for each experiment/animation are presented below with comments.
The first set of experiments shows the properties of liquids (liquids flow, gases occupy all the space available to them, liquids form a surface, the compressibility of liquids and gases is very different, the viscosity of liquids is different). By carrying out the experiments listed in the first set, students learn that gases can flow. They can be seen to take up the entire space available, and some gases are also flammable.

1. Set of experiments: gases can flow and can be compressed
Gases are classified as liquids. Several different experiments can be used to demonstrate the flow of gases. The most well-known experiment is certainly the one - extinguishing a candle with CO2. Pour a little water into a glass and add an effervescent tablet. The jar can be covered, but the experiment succeeds even if it is not. When the effervescent tablet dissolves, CO2 gas is released, which has a density greater than the average density of air, so the CO2 remains in the jar. If the jar is tilted carefully, the gas is poured into another jar. From the second jar, the CO2 is poured back onto the burning candle, which is extinguished. Relight the candle and pour the contents of the 3rd jar over the candle.

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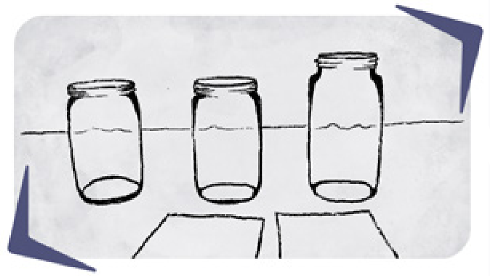
* Conduct an experiment in the same way using vinegar instead of water, and baking soda instead of the effervescent tablet. Alternatively, use water and a mixture of baking soda and citric acid powder.

Findings:
Discuss and summarise the findings with the students. They can be offered with some guiding questions.

Dissolving the effervescent tablet produces carbon dioxide gas (CO2).
How do you know that you have transferred CO2 from the first to the second glass?
What happened when you flowed carbon dioxide from the second jar onto the burning candle?
Why did the candle go out?
What can you say about the density of carbon dioxide compared to the density of air?
How could you show that you have flowed CO2 into the 2nd jar?
What happened when you poured the contents of the 3rd glass over the candle?

The textbook shows an experiment on this topic where a combustible gas from a pressurised container (spray) is sprayed into the first jar. After the gas has been poured from the first jar into the other two jars, a burning match can be used to check that the gas is also present in the other two jars after being poured into the first jar.



Recommendations for the teacher:
The experiment can be carried out in a classroom, but safety precautions must be taken as it is a combustible gas. It is important not to inhale the gas and not to overfill the first jar. Wear safety goggles and gloves.
The work must be properly controlled during the experiment. Discuss the outcome of the experiment and the findings with the pupils. It is important to encourage pupils to reflect on as follows:

- indicators for the presence of gas in the jar,
- the consequences of the gas presence in a small enclosed space,
- the dangers.

When experimenting, they should justify the claim that the gases are flowing.

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They should think about the consequences of dangerous, flammable gases in everyday life.

We can refer to leaks of combustible household gas and encourage students to look online for tips on how to use natural gas safely (https://www.petrol.si/znanje-in-podpora/2019/clanki/nasveti-za-varno-uporabo-zemeljskega-plina.html

Source image: https://www.hippopx.com/en/gas-flames-stove-burner-fire-blue-light-69135

Compressibility is a property that students test when they use the syringe. The purpose of the syringe experiment is for students to notice the difference between the compressibility of water and air. The question in the textbook suggests the possibility that, even with water, pupils may notice that they have partially succeeded in pushing the syringe plunger. The teacher's role (task) is to explain the reasons to the pupils. Water is an incompressible liquid, which may not be obvious from the experiment, therefore a careful observation of the contents in the syringe is necessary. If there was a bubble of air, the pupils were able to compress the air (bubble) but not the water.

Student challenge: How do you fill a syringe with water so that there is no air in it?

The trigger image shows that the position of the syringe should be vertical after filling. In this position, the bubble floats to the top syringe outlet end. With a slight pressure of the plunger, the bubble is squeezed out of the syringe, making sure that it is only filled with water.
Interesting fact: students may observe similar behaviour at the doctor´s. Before injecting (vaccination), the doctor squeezes the air out of the syringe in a vertical position and a jet of fluid can be seen. This is the evidence that the air is no longer in the syringe.

In the following animation, students compare the compressibility of a solid, a liquid and a gas.

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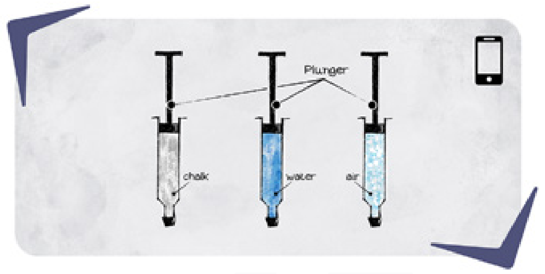
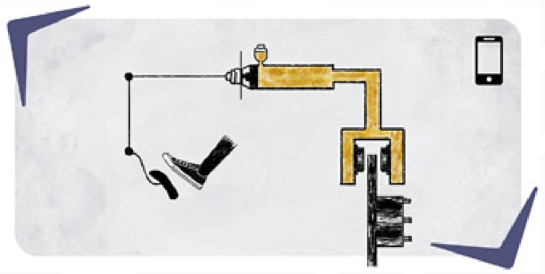


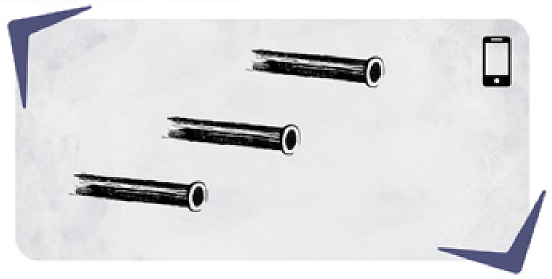
Experiment includes syringes filled with solid, liquid and gas. Students see that solids are incompressible; liquids are hardly compressible, and gases are compressible. In an experiment with water can be seen that the piston of the syringe cannot be pressed. If the syringe filled with water can be compressed a bit, it is due to a small amount of air that gets in a syringe when we drain water into it.

Discuss with students the examples from everyday life. When it comes to transporting of solids, liquids, and gases, we can quickly see that the compressibility of gases comes in very handy. During storage and transport, gases are compressed into cylinders. An example was realised in the first experiment (sprays, natural gas cylinders).



In the following animation, students can get an insight into how a braking system works, where two fluids are present, namely gas and liquid, which have different compressibility.
Students should watch the animation and read the explanation. If they do not understand, they should address the teacher who will direct them to think again about the compressibility of water and air in a syringe.

Viscosity is a property that students can determine, alongside compressibility. From life experience they know that some liquids 'flow' more easily than others. It is worth noting that students often associate viscosity with density. It is the teacher's task to make a clear distinction between the two concepts. Students should watch an animation of liquids flowing out, where the teacher explains that liquids with low viscosity flow more easily.



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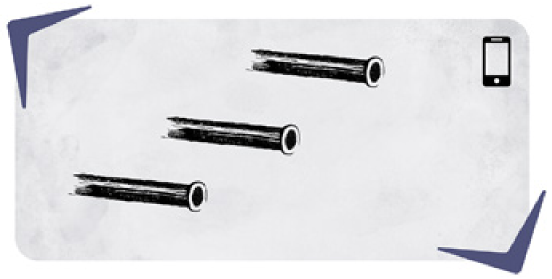
The animation is in English, which can be used to learn technical terms. The teacher may decide to create a glossary of terms for the students to complete as they complete the activity. This way, they expand the possibilities to search for information online also in a foreign language.



When learning about the properties of liquids, it is important that students experiment in addition to watch the animation. In the textbook, there is an example where the magnitude of viscosity is derived from how fast the balls fall in different liquids. The faster the balls fall, the lower the viscosity and vice versa.

Source image: https://commons.wikimedia.org/wiki/File:Honey-PNG-Image-83961.png

The cylinders are filled to the same height with water, oil, and glycerine. Now we compare the viscosity in different liquids and find an important parameter viscosity depends on. Compared will be the time it takes for the marble to fall and reach the bottom of cylinders. For the cylinder with water, we could hardly measure the time, but for glycerine we can do the measurement quite easily. Gather the measurements in a table. From measurements we can deduce that when the measured time is shorter, the viscosity is lower.

We associate viscosity with everyday examples, like honey. Real, natural honey crystallizes, and then it is very difficult to pick it up with a spoon. The problem can be solved by placing a jar of honey in a bath of hot water. Soon we will notice that it becomes more fluid.
The viscosity depends on the temperature. We can also show this with an experiment. We use the same equipment and setup as before, except that we heat all the selected liquids and measure their temperature. We will notice that the measured time of falling in all three liquids is shorter if the liquids have a higher temperature. The results will be more reliable if the measurements are made several times in each liquid at a given temperature (for example, three times) and then the average falling time is calculated.

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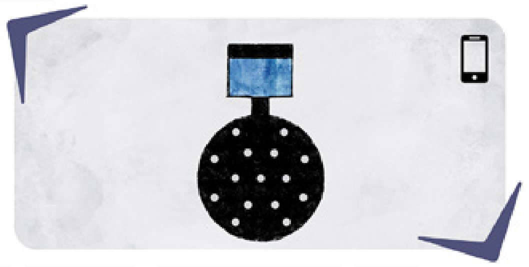
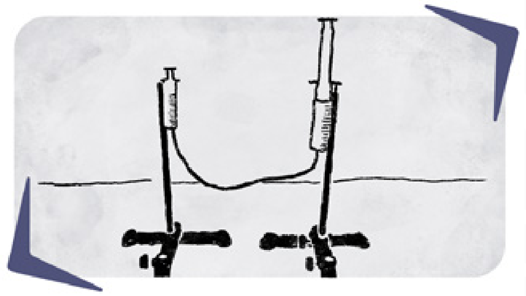
2. Set of experiments: hydrostatics - Pascal's law

When the pressure in the liquid changes, the forces, acting perpendicular to the walls of the vessel, also change. The action of an external force on the wall of the liquid container causes a pressure increase in the liquid, which is transmitted uniformly throughout the liquid. This can be shown by inflating the balloon, as the uniformed inflation can be observed in all directions.

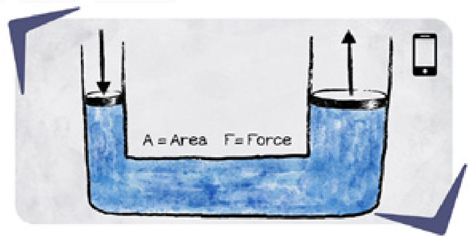
However, the principle of transmission of fluid-pressure given by ***Blaise Pascal*** claims that a pressure change at any point in a confined incompressible fluid is transmitted throughout the fluid thus the same change occurs everywhere. Pascal's Law can be demonstrated with an experiment in which a perforated flask or balloon is placed at the end of a full syringe of water. When the syringe is squeezed, jets of water emerge from the perforated flask. The water jets are perpendicular to the surface and are directed in all directions.





Have students watch the clip and then search online for clips or animations that show the same phenomenon. Have them find one that is more descriptive than the clip they watched. If they do not find one, show students the animation behind the trigger in the figure to the right. The phenomenon is known as Pascal's Hedgehog.

Let's apply what we have learned to the familiar example of two syringes. The syringes differ in diameter. They are connected by a tube and partially filled with water.



It is important that each student tries to vary the pressure of the plunger on one of the syringes, while feeling the effect
on the other syringe. One's own feelings about this experiment are extremely important before turning it into a competition, as suggested in the student materials.

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The characteristics of pressure in liquids are used to advantage in hydraulic and pneumatic devices. An example is a hydraulic jack consisting of two pistons of different diameters.

Pressure in general (which is the ratio between force and surface p=F/S) can be nicely illustrated with examples from everyday life. For example, when you squeeze two walnuts in your fists, it is possible to crush the shell because the force is great, and the contact surface is small. In this case, the pressure is high. When a person wears shoes with a high heel, the pressure on the contact between the shoe and the ground is much greater than when a person wears a shoe with a flat sole. This knowledge/understanding is key to understanding force-surface relationships in the case of a hydraulic jack.

The pistons are connected by a tube filled with fluid. Pressing on the smaller piston causes an increase in the pressure under it and is transmitted to the entire fluid. When the pressures are equal, a greater force acts on the larger piston. The force increases in proportion to the cross-sections of the pistons. Students can develop understanding of the above phenomena through animation, and various mind experiments from daily life.

3. Set of experiments: Hydrostatic pressure

There are quite some misconceptions identified in the literature. Here is a list of some, most common regarding the hydrostatic pressure.

- hydrostatic pressure is inversely proportional to the pipe cross-section.
- the hydrostatic pressure is greater, the smaller the pipe cross-section.
- in connecting containers, the liquid is distributed in such a way that the volume of the liquid is the same in both connected containers, regardless of the height of the surfaces.
- the maximum hydrostatic pressure is where the water level is highest.
- the highest hydrostatic pressure is where the smallest pipe cross-section is.
- the pressure in the liquid at a certain depth is affected only by the height of the liquid above that point.
- hydrostatic pressure only acts on the bottom of the container.
- the hydrostatic pressure is the same throughout the volume of the liquid.

Within hydrostatic pressure activities, teacher must be aware of above listed misconceptions. In the continuation are some suggestions for experimental work and explanations, which can be useful especially when bridging misconceptions.

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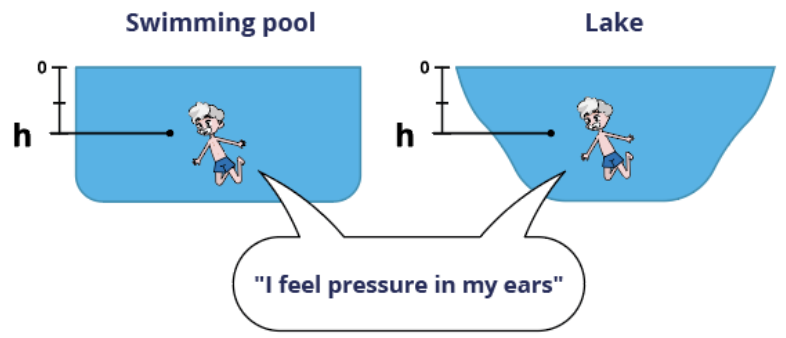
The pressure caused by the weight of a fluid is called hydrostatic pressure. In the students' book an example of hydrostatic pressure in the swimming pool and in lake is presented.



The depth of Arphy in both pools is the same. To determine the pressure in water at marked depth, we must understand that it depends only on the density of water, depth and (external atmospheric pressure on the water surface (water level)). The external atmospheric pressure is placed in brackets since it is left on the teacher when he/she will introduce it. It is possible to discuss about atmospheric pressure at this point or return to this example afterwards when atmospheric pressure is discussed. However, it is important to discuss about the influence of atmospheric pressure on the exact values of the hydrostatic pressure of submerged bodies.

$$p=\frac{F}{A}=\frac{mg}{A}=\frac{\rho Vg}{A}=\frac{\rho Ahg}{A}=\rho gh$$

Students by this point should recognise the water and air as liquids, which means that the air pressure is also a hydrostatic pressure. The equation to be followed in calculation of hydrostatic pressure is written in students' book (on the blackboard). The equation of hydrostatic pressure can be explained as follows.

The liquid in the container can be thought as layers of a substance of a certain weight. The pressure caused by a single layer of liquid depends on the force of the liquid (F) and the area (A) on which it acts.

The pressure caused by a single layer of fluid can be written as p = F/A. If the force is equal to the weight of the fluid, we write F = m g=σ V=ρ g V. Assuming that the volume is V = A h, we can write the pressure caused by the fluid layer as: p = F/S = σ A h/A, p = σ h or p = ρ g h. The equation is written with specific weight that should be used when gas gravitational acceleration was not introduced to students.

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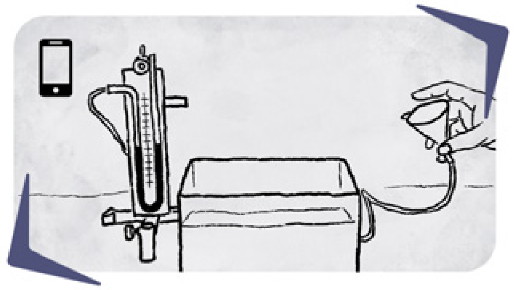
We can see from the theorem that the pressure in fluids increases proportionally with depth. However, to determine the actual pressure in the liquid, we must also consider the pressure above the liquid. The pressure in

the liquids contained in open containers is also affected by the air pressure. In open vessels, this is the atmospheric pressure, denoted p0. The pressure in the liquid in this case is: p = p0 + σ h.

In the example of Arphy submerged in the lake, and in the swimming pool we can conclude, that the pressure on the air drums is the same, since the density of water was by default the same and the depth of the Arphy as well. The thickness of the water layer above Arphy is in both cases the same. If we assume, that the air pressure is the same, the conclusion is correct. An example can be a good starting point for a conversation. We can discuss with the students according to the following questions:

Can you compare the air pressure at the seaside with air pressure at the top of a mountain?
On the web find information on current air pressure at different places in your country. Does information coincide with the answer on previous question?
What if the lake was in the mountains and the swimming pool at the seaside? Would the pressure on Arphy's air drums be the same?
Would the pressure in air drums change significantly if Arphy turns/bend his head?

The answer of the last question can be discussed within the following experiment. U-shaped vessel is filled with a liquid, connected with plastic tube to a funnel-shaped balloon. The height of the liquid columns in the U-tube changes. If the pressure on one side increases, the liquid column on that side decreases. However, we can emphasize another fact. When we compare how air pressure and water pressure change as height (depth) changes, we find that there are significant differences. Immersed in water, the pressure changes more for a given change in height than for the same change in height in air. We feel this in the form of a change in pressure in our ears even when diving to shallower depths.

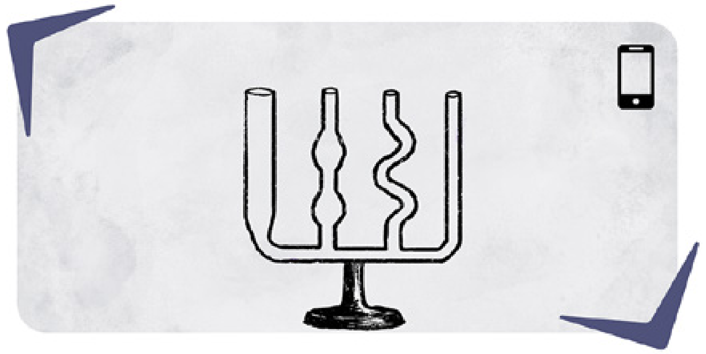


The experiment can be used to show that, at a given depth, the hydrostatic pressure is the same, regardless of direction. Students can try it themselves or watch a demonstration experiment. At the chosen depth, we twist the funnel so that the membrane is at the same depth but changes
direction in space. Students should notice that the difference between the two

columns of the manometer does not change. From this we conclude that the pressure on the membrane has not changed, regardless of its direction in the water.

Another anecdote related to hydrostatic pressure is that in 1646 Blaise Pascal broke a large barrel with water in a long pipe. The pipe was installed vertically. It was filled with water. As the height of the water in the pipe rose, the pressure in the barrel rose, too. At a certain height of the water in the pipe, the barrel would give way and shatter because the pressure was too high.

In the animation behind the figure below can be observed the level of the liquid in vessels of different shapes. We can see that the water level in all connected glass tubes of different shapes remains the same. The pressure in each fluid is always the same at the same depth and does not depend on the shape of the vessel in which the fluid is contained. In the animation we observe that the liquid in all parts of such a connecting vessel is distributed to the same level, which is evidence that the pressure at the bottom of each vessel is the same as it is only affected by the height of the water column and not by the amount of water. This fact is known as Hydrostatic paradox.



From the explanation it becomes clear, why in Pascal's experiment it is possible to break the barrel with only a small amount of water when using a long thin vertical tube.

The principle of the connecting tank can be used in nature or in the construction of buildings to determine the same level over long distances. In the past masons used the principle of connected vessels in device called "spirit level". The water level in the thin transparent plastic tube is the same at both ends of a plastic tube.

Students can demonstrate how masons use a long pipe filled with water (spirit level) to transfer the level from one wall to another. To do this, they need a long transparent pipe that they fill with water. At both ends, the water must not reach the top. One end of the tube is held by one student, the other by another. The height of the water level at both ends of the pipe is the same. Students can align the height of the water level with the objects on the wall and another student marks *the height of the water level on the other wall. By doing this, he has transferred the same level to the other wall, thus both marks are on the same plane, which is horizontal. As a challenge, students can check if the ceiling is horizontal, if the floor is horizontal, etc.*

For this topic, can be mentioned or given example by showing a Pythagorean cup, a simple version of which you can make yourself. More elaborate ones are often found in souvenir shops. The most important component of this cup is the siphon. The siphon is a curved tube, which can be found in various versions both at home and in nature. In any house, there is a whole range

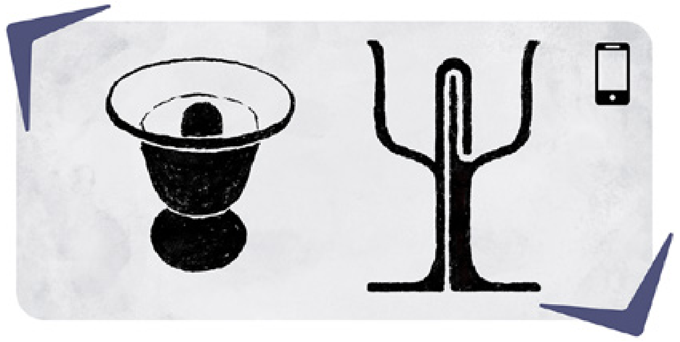
Source image: https://commons.wikimedia.org/wiki/File:Sifonas_2.png

of mandatory containers. Among them are siphons - drain pipes at the sink, bidet, bathtub, shower ... Siphons by their shape allow to retain water in the drainage system, so that the stench from the sewer does not return to the house through the drains.

Siphons are found in nature in the underground tunnels and caves.

Students can search the web and find examples of siphons in nature.
Have students look for siphons at home that are accessible and take photos of them. Have them explain in which part of the siphon the water is permanently located.

A well-known Cup of justice (Pythagorean cup) is a special kind of syphon, where all liquid is drained out if the level of liquid exceeds the upper level of a syphon.



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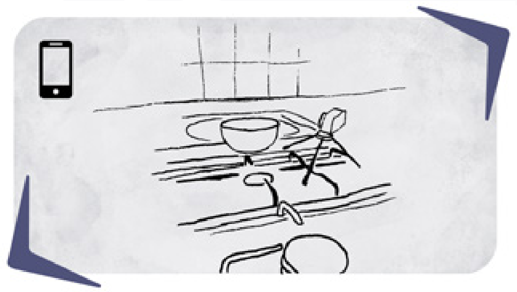
With the animation, have the students explain where the siphon is located and how the Pythagorean cup works.
Have the students make their own Pythagorean cup from the waste packaging (they can use bottles, straws, etc.).

Let us think again about air pressure. When the hydrostatic pressure equation was introduced, we mentioned that pressure changes with depth. Air pressure is a consequence of the air weight. Can we measure the weight of air? In the video behind the following trigger watch how the weight of air can be measured.

We have already said something about air pressure when we introduced the hydrostatic pressure equation. In students book students read the text about the differences in air pressure at the top and at the bottom of the mountain. Human body only detects pressure differences, for example, going up to the mountains with a lift and in other examples of quick changes in height.

In the cloud, Arphy asks a question that students, understanding the relationship between air pressure and altitude, can answer completely independently.

We haven't talked much about the magnitude of the air pressure itself. From the textbook, we can get a sense of the forces acting on our bodies in the air and the magnitude of air pressure.



Air pressure can also compress a can. Through experiment students should realise that the pressure differences play an important role in daily life. When a large pressure difference is created inside and outside the can, so that the outside pressure is greater than the inside pressure, thus the can deforms and compresses. The external pressure has compressed the walls of the can.

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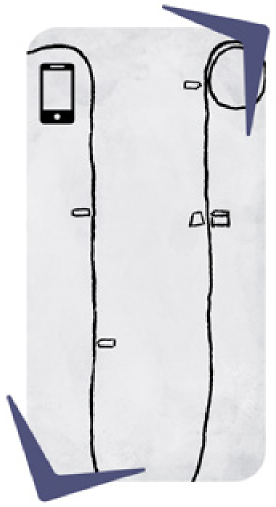

The pressure differences are measured with manometers.

The simplest manometer is a liquid manometer. It consists of a U-shaped tube filled with water. The difference in height of the water level in the tube (Δh) shows the pressure difference Δp. An example of a liquid manometer is presented in experiment behind this trigger.

What is the difference in pressure if the difference in the heights of the water columns on the left and right of the manometer is 10 cm?

Make your own manometer out of a long transparent tube. Determine how much pressure difference you can achieve by blowing into the pipe

4. Set of experiments: Archimedes' Principle

A life story about Archimedes reveals an important milestone in a science development. The Archimedes principle is explained through a series of activities which enables students to comprehend one of the most demanding concepts, a concept of buoyancy.

Learning objectives
As part of the experimental work of this section, students:
- measure the amount of displaced (overflowed) water or objects with the same shape and volume but different density.
  --> Vdispl water = Vobject
- weight the objects in air (Fg) and in liquid (water) (Fin water).
  --> Fin water < Fg -> Buoyancy = Fg - Fin water
- determine buoyancy with Archimedes bucket
  -->Buoyancy = Fg displ water

There arise many **misconceptions related to buoyancy**. Let us list some of them:
- the greater is the weight of the object the better object sinks.
- a more viscous liquid will make the object to float.
- the smaller is the object the better object floats.
- thin flat object floats.
- the pressure of the liquid at the bottom of a beaker/lake/pool and on the water surface is the same.
- the amount of water (liquid) affects buoyancy.

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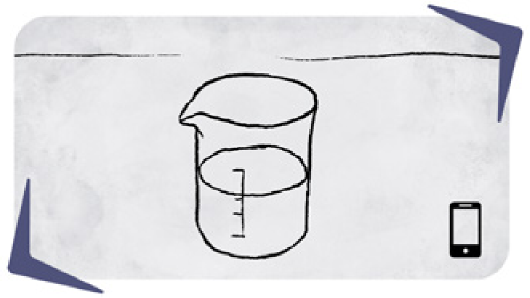
- the shape of the object affects the buoyancy.
- the density of the liquid does not affect the buoyancy.
- the density of an object affects the buoyancy.

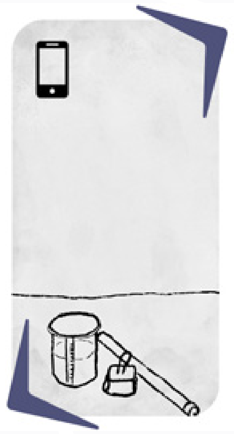
To overcome these misconceptions the following experiments, play an important role. The performance of experiments in the classroom is strongly recommended.

Misconception: *Amount of water influences buoyancy*

Through Experiment 4, students should realize that there is no difference in buoyancy when the same object is placed in different amounts of water. Just make sure there is enough water to allow the object to float unimpeded or sink completely. It is best to take 2 very obviously different sized containers of water, e.g. beaker and aquarium.



Misconception: *Different shapes of objects influence buoyancy*

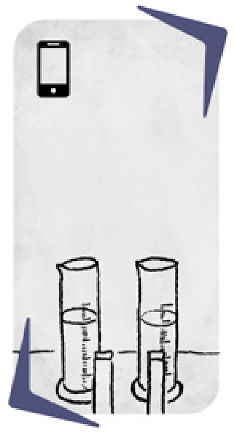


In Experiment 5, students see that there is no difference in buoyancy for the objects of same volume and density, even though the objects have different shapes (cylinder, cube, sphere).

Teacher must be very cautious when choosing the shapes. There can be easily a mistake made if the change of a shape also changes the object's total density. For example, if we use a plasticine ball and reshape it into the shape of a boat, the total density of a boat is not the same as the density of a plasticine ball (we added the air).

Misconception: *A fluid density does not influence buoyancy.*

In experiment 6 two different liquids are used (tap water and sea water) to show that there is a difference in buoyancy when the same object is immersed into each of them. Students should determine the buoyant force on entirely (or partially) submerged object, first in tap water and then in sea water.



They have two options for determining buoyant force: from Archimedes principle, where they measure the volume of displaced fluid. They should realize that

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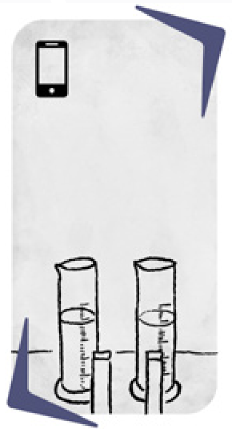
the volume of displaced tap water is the same as the volume of sea water. Students should know that sea water has higher density than tap water. From this fact they can conclude that the buoyant force on the submerged object in seawater is greater than the buoyant force on the object in tap water.

The second option is that they determine the buoyant force from measurements with dynamometer. First, they measure the force of gravity on the object in the air, and then they measure the force, when an object is submerged in each of the fluids. The calculation of buoyant force also reveals that it is grater in seawater.
The teacher should be careful in interpreting this experiment so that it does not lead to misunderstanding by the students. It should be emphasized that we used an object that sinks in the liquids, and we hold it in the liquids with a dynamometer. When using a floating object, students might observe that the object is less submerged in salt water than in tap water. Since this is very difficult to observe, we prefer to use it as a theoretical example. The easiest way to explain it is to represent the balance between the force of gravity and the force of buoyancy acting on an object. Since the gravity of the same object is equal in both cases, the buoyancy must also be equal. However, since buoyancy is equal to the weight of the displaced fluid, in the case where the density of the fluid is greater, the volume of the displaced fluid is smaller. Thus, the liquid density is assumed to be related to buoyancy because the same floating object displaced more liquid in one case. Since buoyancy must be the same in both cases, therefore, in the case where a larger portion of the object is submerged, the density of this liquid must be lower than density of liquid in which the object is displacing less liquid.

Misconception: *The density of an object influences buoyancy*



To show, that density of an object does not influence buoyancy, the same experiment behind trigger on left can be interpreted. But we need to be focused only on one liquid.

Students can easily make an experiment in the classroom, where two blocks of same volume and different density are used. It is recommended to use blocks with higher density in comparison to liquid, so the blocks sink in it. The string should be added to blocks on which we place the dynamometer. Students measure weights of blocks in the air. Afterwards they measure the apparent weight of blocks, when entirely submerged in the liquid. Since the buoyancy is the difference between weight

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and apparent weight, they realise that buoyancy is the same in both cases. Another evidence is that both blocks of the same volume displace the same amount of water, i.e., the buoyant force on both blocks is the same.
--> buoyancy on both blocks is the same- > density of objects does not influence buoyancy if the objects are submerged in the same liquid.

To summarise
In water we have a very special feeling; we seem to become lighter. When we stand in water deep enough, we feel as if we are floating. We feel a force pushing us upwards. This force is called buoyancy.
For floating bodies, by measuring the weight of the displaced fluid and the equilibrium of forces, we can find that the buoyancy is equal to the weight of the displaced fluid. The same thing is found for bodies sinking in liquid when the buoyancy is measured with a force gauge. The bodies attached to the force gauge are weighted in air and in liquid. The difference between the readings is equal to the buoyancy or weight of the displaced liquid. Archimedes' principle states that the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially, is equal to the weight of the fluid that the body displaces.
The equation for buoyancy is written as: $F_b = \rho g V$, where ρ is the density of the fluid and V is the volume of the immersed part of the body / (volume of displaced liquid). The buoyancy depends on the density of the fluid in which we immerse the body, the volume of displaced fluid (which is the same as the immersed volume of the body).
This knowledge helped Archimedes to solve the problem with the crown. If two objects of the same weight have the same density, they displace the same amount of water. Only if the densities are the same, their masses and volumes are the same. So, if we take a block of gold with the mass as it is the mass of crown, the displaced volumes of the water should be the same. As the legend says, this was not the case, Archimedes realized, that the crown does not consist solely of gold, but some other metal (silver) is added.

Hydrodynamics
Hydrodynamics deals with moving fluids. Due to the complexity of the topic, it is not included in the primary school curriculum. It is included in the textbook as the phenomena related to hydrodynamics are everywhere. It is important that pupils have at least some awareness of the causes and consequences of fluid motion. The Italian mathematician Francesco Bernoulli, who discovered the law that as the speed of a fluid flow increases in the horizontal direction, the pressure decreases, was very interested in hydrodynamics. He wrote the law in terms of Bernoulli's equation, which holds in a stationary flow of a non-

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viscous and incompressible fluid and connects two points on a streamline.
The textbook presents an experiment, some examples from everyday life and an additional curiosity from the past in a subsection called Hydrodynamics. We start with what is surely the most famous experiment, when we blow between two cans tied on a string and a few centimetres apart (the experiment works well even if we use two sheets of paper or a balloon). The result of the experiment is surprising, as the two cans come closer together. The experiment shows the relationship between the velocity of liquids and pressure. On one side of the cans, the fluid (in this case air) is moving faster, which means that the pressure is lower on that side than on the other side. The two cans move in the direction of the lower pressure, which means that they are moving closer together.

Two examples from everyday life are described and explained below. First, we explain why there are lines on platforms to indicate where it is safe to wait for a train. Again, it is the movement of liquids, of air, when a train arrives on a platform at a certain speed, causing the air alongside it to move. The reduced pressure can pull us towards the train. The following example describes why the shower pulls the bathroom curtain towards us or towards the water. The explanation is the same as for the train. The water flowing out of the shower causes the air next to it to move. It pulls the curtain inwards because of the lower pressure on the inside.

The chapter concludes with a case in which the windows of a skyscraper in Boston (USA) cracked due to high winds.The last page of the chapter gives some interesting ideas for projects that can be carried out at school or by students at home. All the projects contain the topics covered in this chapter. The projects are undertaken after the material has been (at least partially) covered, so that the pupils already have some background knowledge. Before starting the projects, you should remind the pupils of the steps to be followed during the research (listed at the end of the page). In school, you can organise work in groups, where you have several options - you can present the same problem (project) to all the groups, or you can have the groups work on their own problem.

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ARPHYMEDES

CHAPTER 5

WORK, POWER AND ENERGY

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WORK, POWER, ENERGY

What is... Work?
"Work is energy transferred to or from an object by means of a force acting on the object. Energy transferred to the object is positive work, and energy transferred from the object is a negative work" (Halliday, Resnick and Walker, 2001).

Power?
"The time rate at which work is done by a force is said to be the power due to the force. If an amount of work is done in amount of time by a force, the average power due to the force during that time interval is Pavg = W/Δt" (Halliday, Resnick and Walker, 2001)

Energy?
In Greek the word means activity, by which Aristotle meant the transition from the possible to the actual. In all languages, the word was associated with the activity and liveliness of people and other living things. It was not until the 19th century that it acquired a physical meaning (Strnad, 2003). However, in physics "the term of energy is so broad that a clear definition for it is difficult to write. Technically, energy is a quantity that is associated with the state or condition of one or more objects" (Halliday, Resnick and Walker, 2001). When describing energy, a system needs to be defined. The system may contain one or more objects. Energy is a quantity expressed in number and unit (Joule) addressed to one system.

Operational learning objectives

Students will be able to:
- explain that physical work depends on the force and the distance over which the force acts on the object.
- use the equation to calculate work and become familiar with the unit.
- understand that a force acting perpendicular to the direction of motion does not exert work on the object.
- recognize among the forces acting on a moving body the forces or components of forces that do work.
- know that kinetic energy is related to motion and that a change in kinetic energy is related to a change in speed.
- know that kinetic energy depends on the mass and speed of the body.
- use the equation to calculate kinetic energy.
- explain that the change in potential energy is related to the change in position of the body in the vertical direction.
- apply the equation to calculate the change in potential energy.
- understand and apply the theorem of conservation of mechanical energy.

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- explain that the energy can be converted from one form to another.
- define power as the quotient of work and time in which the work is done. (Bajc et al., 2011)

Common student misconceptions

Regarding the literature review, students have many misconceptions about force, work, energy, and power. Based on articles in the references, the following list of misconceptions was created. The teacher should read it carefully, as it offers clues for work and conversation with students. A teacher who realizes common misconceptions in a particular topic can be more goal-oriented and pay attention to expressions, speech and selected examples.

Within misconceptions students often
- misunderstand the concept of force.
- misunderstand Newton's third law.
- believe that force is innate property of an object rather than an interaction between objects.
- believe if an object is at rest, no forces are acting on the object.
- believe that doubling the speed of a moving object doubles the kinetic energy.
- believe, that the motion of an object is always in the direction of the net force applied to the object.
- believe, energy is a force.
- believe that energy is lost in transformations from one type to another.
- believe energy can be lost when transferred from one object to another.
- believe kinetic energy depends on mass only.
- believe kinetic energy can be negative when object moves to negative direction.
- believe that gravitational potential energy depends only on the height of an object.
- believe an object in rest has no energy.
- believe energy of any system is constant.
- fail to interpret the statement "energy is conserved" correctly.
- have tendency to associate work with a change in either kinetic or potential energy rather than in the total energy.
- have tendency to treat the sign of the work as depending on the coordinate system.
- fail to recognize that an energy analysis depends on the choice of system.
- failure to recognize that any group of objects can be treated as a system.
- associate energy with living objects.
- associate energy with movement.

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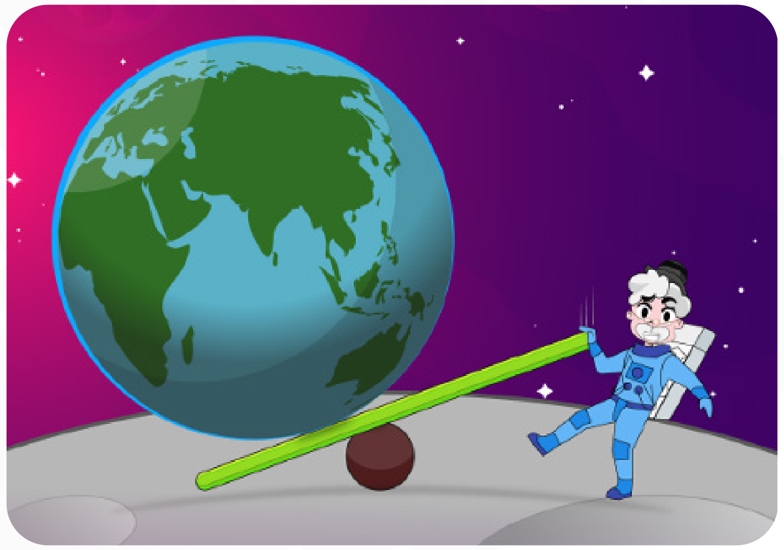
Chapter cover

When it comes to work, the examples often apply to work with tools (lever, pulley, slope). When dealing with tools in experiments, we explain to the students that the work does not change when the tool is used, only the force is smaller, which means that it must act over a longer path. One of the tools is a lever, where a small force is used to act on a longer path. In doing so, we push down on the longer side of the lever while lifting the heavy load on the shorter side of the lever. A well-known anecdote about the lever is associated with Archimedes and is also mentioned in the chapter Mechanics of Fluids.

Archimedes is reported to have said, "Give me a solid point, and I will lift the Earth". You can refer to this example and even calculate how long the rod would have to be if such a lever could be placed in a space. Look up the data on the mass of the Earth on the Internet, and then estimate with the students the maximum force the student can exert on the end of the longer part of the rod (you can use the student's weight). The calculation also requires estimating the length of the shorter part of the rod. The reasoning should be along the lines that the point where the Earth touches the rod will be at its end (and not at the point shown in the picture). Discuss the calculation and distances with the students and conclude that such a lever cannot be placed in a space.

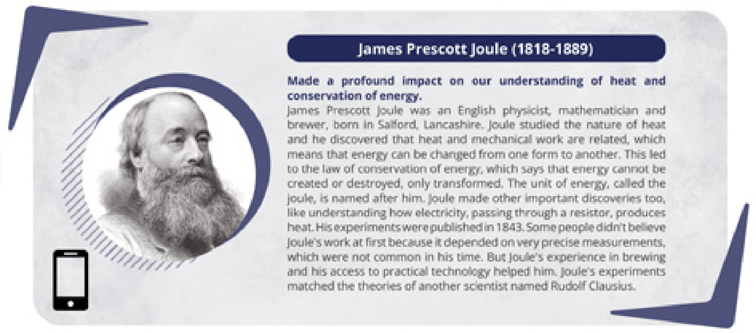


Famous scientists

This chapter presents three important men who have contributed to the advancement of physics knowledge in the fields of energy, heat, work, and power.

James Prescott Joule (1818-1889) was the son of a wealthy brewer, so he could afford his own laboratory. In the laboratory he devoted himself to physical research as he was very good at experimental work. He first worked on electricity and magnetism and continued the research in the field of heat and temperature. He measured heat in a variety of changes, such as when water

falls in a waterfall, when water is mixed or flows through pipes, when gases are compressed. He measured the mechanical equivalent of heat. Because he was not a physicist, his work did not initially attract much attention. When his work was noticed and supported by Lord Kelvin, Michael Faraday, and others, he was made a Fellow of the Royal Society. The unit for energy, work and heat was introduced much later in his honour (Strnad, 2003, 1990, von Laue, 1982).



Rudolf Emanuel Clausius (1822-1888), together with Lord Kelvin, derived the second law of thermodynamics. The energy law represented an important turning point in physics, as it introduced the concept of entropy.

William Thomson, Lord Kelvin (1824-1907), introduced the second law of thermodynamics by the example that there can be no engine that repeats the thermodynamics cycle and produces only work if only heat is supplied to it. With the given work, one could heat the body in the environment above the original temperature and thereby achieve the same thing as transferring heat from the body to a warmer body. Such a heat machine, which would contradict the second law of thermodynamics, is called a perpetual motion machine of the second kind. There is also the term perpetual motion machine of the first kind, which contradicts the law of energy (the first law of thermodynamics) (Strnad, 2003, 1990, von Laue, 1982).

Have students watch the animation about J.P. Joule. You can also share the above facts with students during the discussion, considering their interests and abilities. All three scientists were contemporaries because they lived in the 19th century and knew each other's work. Talking about these three famous people provides opportunities to review and learn units, explore perpetual motion machines, experiment with heat, etc. Below are some prompts for conversations and work.

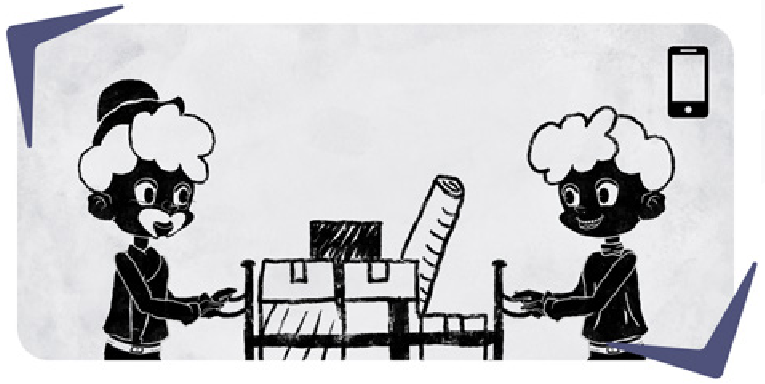
Which physics quantity has the unit kelvin? Is it also measured in any other units? Find information on the Internet.
Find a thermometer that has a scale with two different units (degrees Celsius and degrees Fahrenheit). Read the air temperature in both units. (Note: The teacher should provide such in advance.)
Find the conversion formula from Fahrenheit to Kelvin and Celsius to Fahrenheit.
Would you attribute the temperature of 82°F to summer or winter outdoor temperature?
What is a joule? How is this unit defined? Why do you think it is named after James Prescott Joule?
Choose a food and look on the package to see what its total energy value is. You will notice that the total energy value is written in joules and cal (calories). What is the meaning of the "k" in the units kJ and kcal? Finally, calculate how many joules are in 1 cal.
Look at the map of Europe and determine in which countries and cities Clausius, Kelvin, and Joule worked and lived in.
Find designs of perpetual motion machines on the Internet and discuss why they cannot possibly work.

Experiments and animations

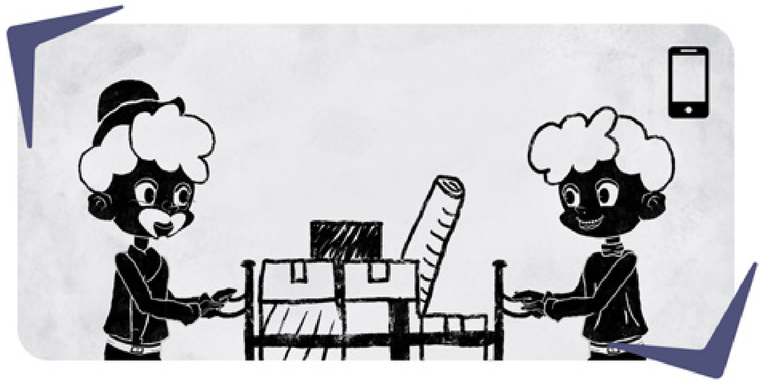
The chapter contains a series of animations and a video on the learning topic of work and energy. The teacher can use them when introducing new concepts. They can also be used for repetition or simply to keep students' interest. As mentioned in the introduction, animations can serve as a starting point for experimental work. In the classroom, you can conduct experiments with your students like those presented in the animation. In all cases, the role of the teacher is important, as he or she provides an explanation, explains the instructions to the students, organizes the experimental work, or reviews the results of the students' independent work.
The first animation is used to show the definition of the term "work". Discuss with the students about the role of the force of gravity and the force of the base.

In the second animation, we emphasize the contribution of two forces acting on the observed body in the direction of motion.

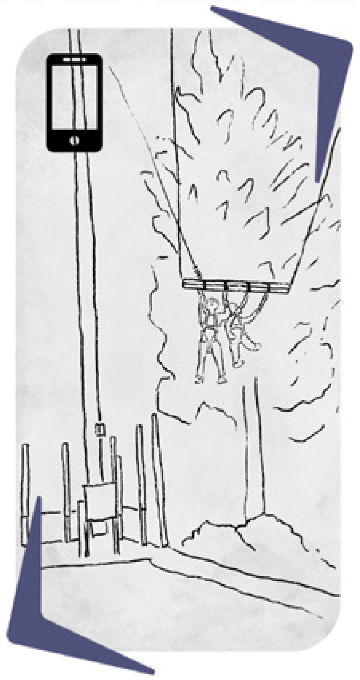
In the third animation, we emphasize the contribution of two forces acting in opposite directions. In the materials for students, examples are given wheree the forces are not parallel to the direction of displacement. Only the components of the forces that are parallel to the displacement affect the work. The mathematical expression in calculation of components includes angular functions, which are not yet considered by elementary school students in some counties. In this case, such tasks are solved by scale drawing of forces and measuring the corresponding components of the forces.



In the last animation in the section on work, there is a case where the forces act on the car in a direction that is not parallel to the direction of displacement (and motion).



When capturing the trigger image below with the app, a video of swinging on a giant swing is playing. Along with the video, we can talk about energy conversions during the swing's oscillation, the influence of air resistance, and the work of air resistance. In addition to the energy-related tasks found in the student materials, you can carry on the example with a power task. With the students, you can also determine with what power the device used to bring the persons to the starting position before descending (you can measure the time, estimate the change in height, and estimate the weight of persons). Discuss the ideal case (what we ignore, what we assume) and the real case.



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