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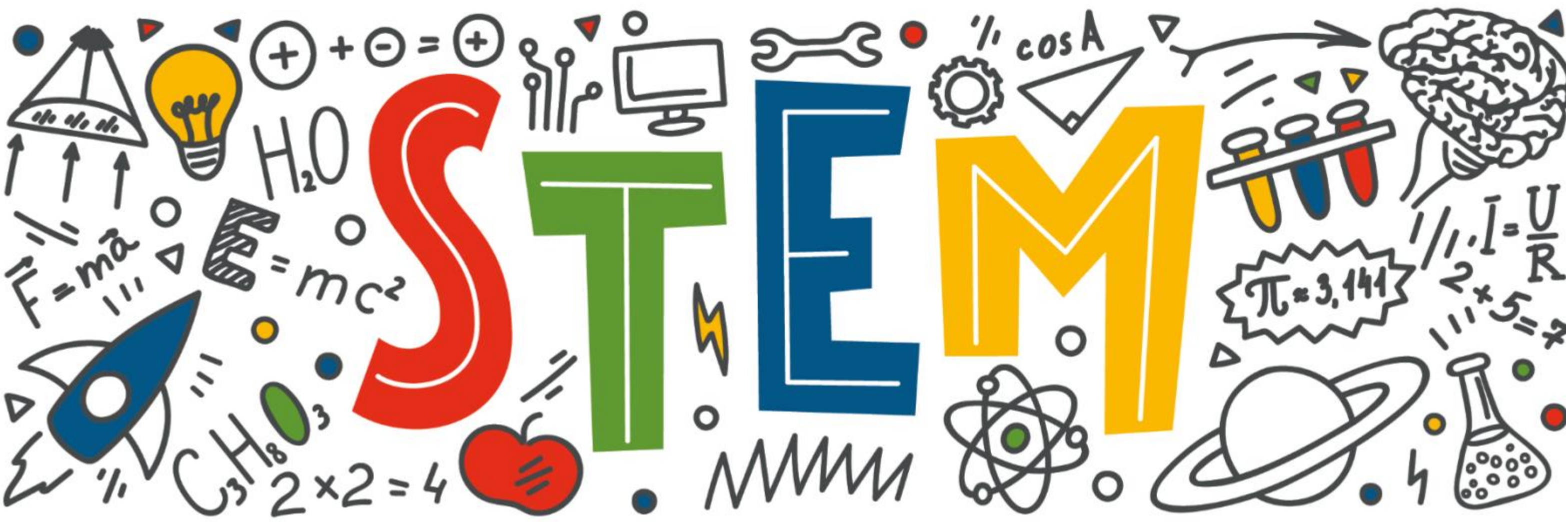
Simple machines in
SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS



A METHODOLOGICAL GUIDE FOR TEACHERS TO DESIGN AND DELIVER ONLINE COURSES

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A methodological guide for teachers to design and deliver online courses

The purpose of this guide is to support teachers to design and deliver courses in a pure distance or blended learning (combination of face to face and distance learning). Distance learning can be implemented in the form of e-learning, computer-supported learning or online learning. We present in brief the main typical or noticeable features of these three approaches. All of them are instances of digital learning.

The term e-learning refers to the provision of content to individual students through digital means, i.e., Internet and/or multimedia platforms. In this kind of learning, **the teacher is the "knowing person",** while students must follow his/her instructions. We could say that it is a kind of a behaviorist-learning paradigm.

The computer-supported learning is centered in **collaboration among learners** through the use of connected computers. It can be used for pure distance learning or blended learning (which combines face-to-face and distance learning). In this type of learning we assume that **one learns through collaboration with others.** The teacher's role is to facilitate the interaction among students for the creation of the meaning.

During the online learning, students choose the appropriate information from the sources that he/she has in his/her disposition and **gradually built on it, giving it a meaning. The teacher is just a facilitator**, responsible for the provision of the learning environment and the negotiation of the objectives. Corsera is an example of a digital platform enabling for the online learning. The pedagogical background of the online learning is the cognitivism.

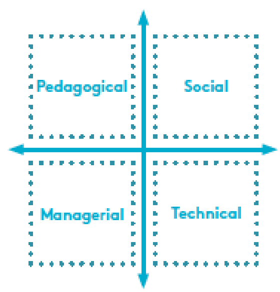
The role of the teacher as e-facilitator

To Ilgaz and Gulbahar (2015) the e-facilitator's role and competency should stretch along four dimensions: pedagogical, social, managerial, and technical.

Ilgaz, H. and Gulbahar, Y. (2015). A Snapshot of Online Learners: e-Readiness, e-Satisfaction and Expectations. International Review of Research in Open and Distributed Learning. International Review of Research in Open and Distributed Learning, 16(2):171-187.

- The pedagogical dimension refers to the facilitator coaching and assessing expertise.
- The social dimension refers to interpersonal and communication skills.
- The managerial dimension refers to administrative and organization skills.
- The technical dimension refers to technological literacy.

Four dimensions of e-facilitation



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Rules for e-communication

Because proximity is often missing in online learning, clear and effective communicator must ensure that **communication among participants is effective.**
The 'golden rules' that he/she must share with students are:

1. Every speaker should limit statements to a single topic and make another statement later, if needed.
2. If several participants must accomplish the job, make sure that there is clarity about the work process, with specifics about who does what and when. This awareness is fundamental for setting up the entire communication process.
3. Maintain a frequent (daily) and steady communication with the participants.
4. Do not be afraid to ask questions. Also, acknowledge when you do not know something and accept constructive criticism.
5. The shared information should also be accessible and available to all.

The theoretical model behind the proposed design

The theoretical model behind the proposed design of **a unit on the SIMPLE MACHINES** is the "Backward Design" introduced in 1998, by Grant Wiggins and Jay McTighe in elaborated in their book Understanding by Design (2005). Backward design is an approach to instructional planning that starts with the end goal, then works backward from there. Planning the assessment before the planning of a lesson means to 'know where you're going' and encourages you to plan for that destination, visualizing the end and moving backward in sequence. It's a design model that can make a big difference.
Here are the 3 stages of a backwards design:

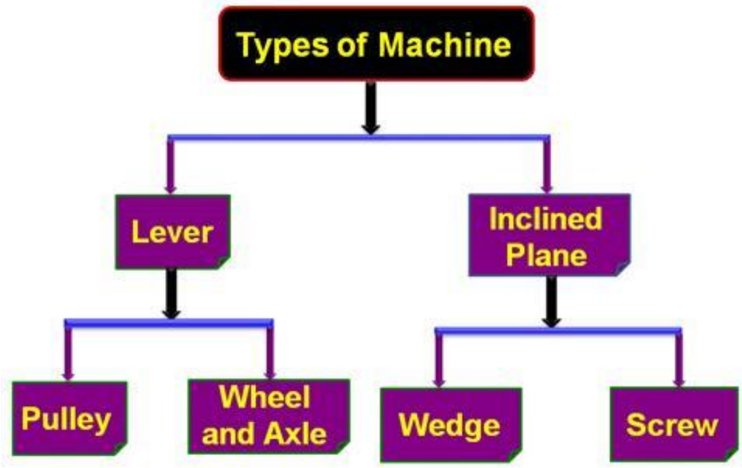
- **Stage 1**: Identify what students should know and be able to do by the end of the learning cycle.
- **Stage 2**: Create an assessment to measure that learning.
- **Stage 3**: Plan a sequence of lessons that will prepare students to successfully complete the assessment.

Wiggins, G. P., Wiggins, G., & McTighe, J. (2005). Understanding by design. Ascd.

Simple Machines

Simple machines are devices used **to transfer energy to accomplish tasks that would otherwise be more difficult or impossible to complete without the use of the simple machine**.
A simple machine is a device that helps us to lift heavy loads or speed up motion or change the direction of force in a desired direction.
In other words, simple machines typically **operate by decreasing the amount of effort force that the used must supply**, however the trade-off is that the user must exert this force over a larger distance.
Complicated machines are made from two types of simple machines:

- Lever
- Inclined plane



A lever is a rigid bar, which can rotate about a fixed point or a fixed line called axis of rotation or fulcrum.

- In a lever of the first order, the fulcrum is situated between the load and the effort, like in scissors, water pump, plier etc.
- In a lever of the second order, the load is situated between the effort and the fulcrum, like in wheel...
- In a lever of third order, the effort is situated between the load and the fulcrum, like in sugar tongs, bread knife etc.

Pulley and the wheel and axle are based on the working of a lever.

- Pulley is a flat circular disc having a groove in its edge and capable of rotating around a fixed point passing through its central axis called axle.
- Wheel and axle consist of two cylinders of different diameters joined together in such a way that if one rotates, the other also rotates.

Inclined plane is any flat surface with a slope along which a load can be easily pushed or pulled. A double inclined plane is called a wedge, which is used to tear apart solid objects.
Some of the modifications of wedge are axe, hammer, knife and chisel. A rotating inclined plane is called a screw. It is generally used to fasten two pieces of wood or metal. Some other examples of screws are corkscrew, screw jack etc.

From the Unit of Simple Machines, we present here -as an example- a sub-unit on Pulleys.

But even the sub-unit on Pulleys contains many lessons with specific objectives each one.
So, in the actual document we present in detail two lessons as the Italian expert team, and the Greek expert team designed them.
The objectives of both teams were the same. The difference is on the methodology adopted, the different ways to obtain data: a simulation or a real experiment. A measurement during a real experiment is a more complex activity, even in the cognitive aspects.

STAGE 1: Desired Results

- What meanings should students make in order to arrive at important understandings?
- What essential questions will students explore?
- What knowledge and skill will students acquire?
- What established goals/standards are targeted?

A) Understand the nature of Scientific Inquiry

- A1. Students should know and be able to:
  - Should know that: Scientific investigations involve asking testable questions. Different kinds of questions suggest different scientific investigations.
  - Be able to: Frame and refine questions that can be investigated scientifically and generate testable hypotheses.
- A2. Students should know and be able to:
  - Should know that: A valid investigation controls variables. Different experimental designs and strategies can be developed to answer the same question.
  - Be able to: Design and conduct investigations with controlled variables to test hypotheses.
  - Be able to: report the results obtained in an experiment using: videos, reports and multimedia presentations
- A3. Students should know and be able to:
  - Should know that: In a scientific investigation, data collection involves making accurate measurements, evaluating measurement errors, and keeping accurate records so that others can replicate the experiment
  - Be able to: Accurately collect data through the selection and use of tools and techniques appropriate to the investigation. Construct tables, diagrams and graphs, showing relationships between two variables, to display and facilitate analysis of data. Compare and question results with and from other students.

B) Force, Energy and their Effects

Students should know that:

- When the forces acting on an object are balanced, its motion will not change. Unbalanced forces will cause the object's motion to change. Changes in motion depend upon the size and direction of the total unbalanced force exerted on the object.
- Gravity is a force that acts between masses over very large distances. Near the Earth's surface, gravity pulls objects and substances vertically downward.
- The tension is a pulling force that acts along a stretched flexible connector, such as a rope.
- Forces can be used to transfer energy from one object to another. **Simple machines are used to transfer energy in order to simplify difficult tasks.**
- **Simple machines may change the direction of an applied force (directional advantage) or the size of the force that is applied (mechanical advantage) but that the amount of energy transferred *by* the simple machine is equal to the amount of energy transferred *to* the simple machine**
- Changes take place because of the transfer of energy. Energy is transferred to matter through the action of forces. Different forces are responsible for the transfer of the different forms of energy.
- The effort force and the effort distance form an inverse relationship (sometimes described in terms of "trade-off"). This relationship stems from the fact that it takes a specific amount of energy to complete a given task.

C) Specific Objectives of the designed course

- **A. Students should know that:**
  - All simple machines operate on the fact that the input energy is equal to the output energy, but the effort force and effort distance are most likely different from the load/resistance force and load/resistance distance.
  - The ratio (comparison) of load/resistance force to the effort force is called the mechanical advantage (MA).
  - Directional advantage in a pulley system can create an advantage for the user.
  - Mechanical advantage in a pulley system can create an advantage for the user.
  - Energy input in a pulley system is equal to the effort force multiplied by the effort distance.
- **B. Students should be able to:**
  - B1. **Make observations** of pulley systems and draw conclusions using data.
  - B2. **Identify**:
    1. the effort force,
    2. the pulley (as either fixed or moveable), and
    3. the resistance force in pulley systems.
  - B3. **Investigate the effect** of using fixed and moveable pulleys on
    1. the effort force,
    2. effort distance, and
    3. the mechanical advantage of a pulley system

- B4. **Investigate and describe**
  1. the effort force & effort distance relationship in pulleys.
  2. compare the force and distance relationship in terms of energy using the terms effort force, effort distance, and energy.
- B5. **Distinguish**
  1. between a mechanical advantage and a directional advantage.
- B6. **Identify**
  1. the advantages (mechanical or directional) of different pulley systems.
- B7. **Explain**
  1. mechanical advantage in terms of force and distance.

STAGE 2: Assessment Evidence

- What performances and products will reveal evidence of meaning- making and transfer?
- By what criteria will performance be assessed, in light of Stage 1 desired results?
- What additional evidence will be collected for all Stage 1 desired results?
- Are the assessments aligned to all Stage 1 elements?
-

GROUP OF ITALIAN EXPERTS

A) ASSESSMENT RUBRIC

	Needs improvement	Fair approaching grade level	Good grade level	Excellent
Knowledge	Little knowledge of the nature of tension force and force diagram Little knowledge of the functioning of the fixed and mobile pulleys.	Some knowledge of the nature of tension of a rope, basic use of the force diagram basic knowledge about functioning of the fixed and mobile pulleys.	Knows the nature of tension of a rope, Draws the force diagram Knows the functioning of the fixed and mobile pulleys.	Knows the nature of tension of a rope, Draws the force diagram completely and correctly Knows the functioning of the fixed and mobile pulleys and is able to relate them to the functioning of the hoist.
Thinking	Doesn't identify some fundamental forces, i.e. weight or tension, so it is not possible to analyse the strength gain. His ideas are vague.	Recognizes all the forces involved in the hoist, guesses the gain in force from the use of the hoist, but doesn't explain the concepts.	Recognizes all the forces involved in the hoist, is able to understand the gain in force from the use of the hoist. Understands that there could be a connection between gain in	Recognizes all the forces involved in the hoist, is able to understand the gain in force from the use of the hoist. He understands that the gain in strength

			strength and lost in displacement.	corresponds a lost in displacement.
	Needs improvement	**Fair approaching grade level**	**Good grade level**	**Excellent**
Design/ Construction	The apparatus is made in a messy and/or careless manner. There is no attention to the detail and there are some elements falling or missing.	Project is somewhere nearly done with some attention to detail. Applies some of the required skills related to the use of pulleys.	Project is nearly done, organized and has some attention to detail. Is able to build the hoist, carries out the proposed experiment.	Is able to correctly build the hoist, carries out the proposed experiment and verifies its purpose (question 5).
Communication: videos and with other members of the group	Explains with limited effectiveness, explanation has none/few science terms, videos are poor or irrelevant, unclear and doesn't help to show how system works.	Explain how system works with some effectiveness. Explanation has some science terms; videos show some important aspects of the system and are somewhat organized.	Explains how system works with effectiveness. Explanation includes many science terms. Videos contain most important aspects of the system.	Exchanges necessary and effective information that includes correct science terms and records videos to create the final product, which is uploaded to the platform. Complete and clear video and presentation.
Application	Does not apply facts or information to solve the problems.	Applies some knowledge of pulleys to solve some problems about the hoist.	Is able to solve almost all the problems about the hoist.	Is able to solve the problems about the hoist completely and correctly (question 3, 5 and 9).

B) SELF ASSESSMENT

B1) True / false questions (First level)

- The hoist is a simple machine (True False)
- The rope passing ring of a hoist can be replaced with a mobile pulley to obtain the same mechanical advantage (True False)
- With a hoist it is possible to keep in equilibrium a mass *m* with a mass *m/4* (True False)

B2) Complete the following sentences: (Second level)

- In a hoist a mass of 50 kg is balanced by a mass of ....
- In a hoist a mass of 50 kg is held suspended by a force of ....
- In a hoist, a mass of 100 kg is lifted by 20 cm by a force F applied to the end of the hoist rope so the point of application of the force F moves by ....

Can you justify your assertions?

B3) Answer the following questions (Third level)

- Can you explain to a friend in detail how to build a hoist? What would you tell him/ her?

- Can you explain to a friend what is the advantage of using a hoist to lift a weight? What would you tell him/ her?
- Which part of the hoist a movable pulley to achieve the same gain in strength can replace? Explain why.

GROUP OF GREEK EXPERTS

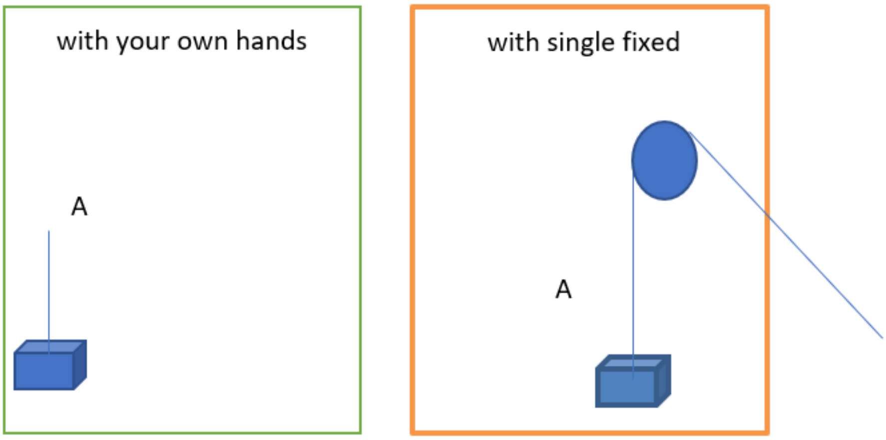
A) ASSESSMENT RUBRIC

	Needs improvement	Fair approaching grade level	Good grade level	Excellent
Knowledge	Can't draw the forces on a body. Can't distinguish between the effort and the load	Draw the forces on a body with mistakes. Can't distinguish between the effort and the load	Draw the forces acting on a body with a few mistakes. Able to distinguish between the effort and the load	Draw all the forces acting on a body. Able to distinguish between the effort and the load
Thinking	Can't realize the advantage by using the single stable pulley. Can't fill the table of the worksheet. The majority of the results is wrong or missing	Can realize the advantage by using the single stable pulley but not the others Many results are wrong or missing	Can realize the advantage of using the different kinds of pulleys A few results are wrong or missing	Deep understanding of using different kinds of pulleys All the results are correct
Communication	Explains how pulleys work with limited effectiveness. Explanation is unclear and has none/few science words/terms	Explains how pulleys work with some effectiveness. Explanation has some science words/terms	Explains how pulleys work with effectiveness. Explanation includes many science words/terms	Clearly and effectively explains how a system of pulleys work.
Design/ Construction	There is no attention to the application's items. Can't make the necessary changes in the application	Project is nearly done with some attention in details. Uses the simulation without understanding	Project is nearly done with the required attention in details. Uses the application without any major problems	Project is done with the required attention in details Uses the application without any problem
Communication with other members of the group	Either no messages were sent, or the messages were irrelevant to the experiment	A few messages were sent but with no clear content	A few messages were sent with clear content	Messages with clear content and necessary information
Application	Can't solve a problem by using pulleys.	Can create a design with pulleys to lift an object with some effectiveness.	Can create a design with pulleys to lift an object. Cannot calculate the force needed	Applies knowledge of pulleys and mechanical systems to create a design that successfully solves the problem

		Cannot calculate the force needed		with a high level of effectiveness. Can calculate the force needed

B) SELF-ASSESSMENT TEST

1. Draw the body's weight and the force need (point A) to lift the body



2. You want to lift a 500N load by using a single fixed pulley. How many Newtons will be your force? ……………
3. Why shall we use a single fixed pulley?...
4. You want to lift a 500N load by using a single movable pulley. How many Newtons will be your force? ……
5. What is the main advantage of using a system of pulleys?
   ....
6. You want to lift an object in a specific height where the body's potential energy is 400J greater. How much work you need when you use:

   a. your own hands ……………………………

   b. a system of pulleys ……………………….….
7. You use a triple compound pulley to lift a 180N load, 3m higher.

   a. How many Newtons will be the effort?..

   b. How many Joules will be the work needed? ……………………………….
8. Parthenon is the temple that dominates the hill of the Acropolis at Athens. It was built in the mid-5th century BCE. The temple is generally considered to be the culmination of the development of the Doric order, the simplest of the three Classical Greek architectural orders. The colonnade, consisting of 8 columns on the east and west and 17 on the north and south. Each

column consists of huge marble pieces. Measured by the top step of the base, the building is 31 meters wide and 70 meters long. Building the Parthenon was a technologically innovative and, of course, extremely difficult task for the ancient Greeks. They managed to extract, transport 20km far from Penteli mountain and lift huge quantities of marble to the rock of the Acropolis, with their technology.

Design a mechanical system that the ancient Greeks may have used to lift these huge marble pieces and build this great monument.

BOTH GROUPS OF EXPERTS

IF WRITING A FINAL REPORT IS A WAY OF ASSESSMENT YOU WILL CHOOSE, TAKE INTO CONSIDERATION THE FOLLOWING:

There is no rigid scheme for drafting an experimental report, but the essential points to consider are the following:

1. Title of the activity
2. Author of the report, class and school year
3. Members of the working group in the laboratory, or at home
4. Purpose
5. The theoretical aspects of the activity: indication of the mathematical relationships between the quantities involved in the experiment and the physical laws that justify it, considerations and approximations that allow their application.
6. Tools, measure instruments and materials
    - What did you use? What is the sensitivity and scope of the measure instruments used?
7. Procedure
    - In this part the practical aspects should be clarified: what have you done if you have devised a particular method or some precaution in the use of the material available to improve the execution of the experiment.
8. Measurements and Measurement Errors
    - An experiment usually provides a set of numerical data, obtained from measurement operations. All these data must appear in the experimental report organized in tables. It is fundamental to assign a title that identifies each table. The measures must be in sufficient number to draw the right conclusions. When taking measurements in the lab, do a preprocessing to see if you need to do a number or a few more. Each experimental work necessarily provides data affected by errors and their size can make the experiment completely useless. It is therefore important to include an explicit evaluation, as accurate as possible, of the errors and then determine the effect on the final results. Remember that the accepted convention is that only one significant digit is to be reported for errors. The errors must be entered in the measurement tables and in the values shown on the graphs. The proposed results must have the correct number of significant digits and this is determined by their error.
9. Data processing

- All the calculations, such as averages and calculations made on the measurements, based on the relative formulas and the procedure must be reported. If possible, it is also a good idea to organize the results of the calculations in tables. When using the pocket calculator, it is recommended not to round (or worse to truncate) any intermediate results, but to keep all the figures and then arrange the correct number of significant figures in the final result. Sometimes some measurements are obtained from a graph, for example the determination of an area or the slope of a straight line identifiable from the data. It is good to explicitly indicate what has been done.

10. Graphs

- They are very useful for underlining a relationship between quantities and must be plotted on graph paper, especially when measuring operations on the graph are foreseen. They must be clearly drawn and with well-marked scales. You must be careful to choose the units of measurement on the two axes well, in order not to have a graph that is all squashed on the horizontal or vertical axis or that does not highlight what is of interest. The errors must be clearly visible in the experimental points shown in the graph. The units of measurement must be well indicated on the axes. It is usually a good idea to avoid reporting the values of the measurements made on the axes (they are already written in the table).

STAGE 3: Learning Plan

During the design of the Learning Plan decisions are taken at

- the micro-level (relating to individual activities and their immediate contexts)
- the meso-level (relating to flows of tasks as the design is progressed)
- the macro-level (relating to course/ program objectives) interacts.

For the macro-level of design, it is useful to think in terms of 4 questions:

1. What is the objective of the course?
2. What are the profiles (knowledge & experience level) of the students? What they already know?
3. What resources (content and laboratory equipment) will I need? Do I have access to these resources?
4. What technology (ICT) will I need to support learning?

For the meso-level of design, it is useful to think in terms of 4 questions:

1. What is the best learning trajectory?
2. Have I considered tasks of different cognitive demand?
3. What will be the flaw of the tasks so as some of them to function as eventual hints?
4. What kind of formative or/and summative assessment I will apply?

The micro level is the actual level of design. In our guide we apply Gilli Salmon's (Salmon, 2011) model for a micro design.

Salmon, G. (2011). E-moderating: The Key to Teaching and Learning Online. Routledge.

Salmon suggests 9 steps to design a good e-activity.

We will present these steps through an example in the context of simple machines.

STEP	DESCRIPTION
1. Title	**Move it!**
2. Purpose	**The activity will allow you to:** To know the six simple machines and to understand what they do and how they have changed the lives of humans.
3. Task overview	**A machine-detective:** Simple machines are "simple" because most have only one moving part. When you put simple machines together, you get a complex machine, like a lawn mower, a car, even an electric nose hair trimmer! Remember, a machine is any device that makes work easier. In science, "work" means making something move.
4. Motivation/ Sparks	**https://www.youtube.com/watch?v=BU4AJRR39hs** **See also the text below**
5. Participants tasks	**Now you're ready to observe and record.** – Find and observe at least one simple machine that's used in your home, school, or community. **Exchange your findings in the community.** – Answer the questions below. **(See below)** – **Discuss with the students of your team your answers.** – Finally, write your report, prepare a PPT presentation and upload it to the platform. (**See below**)
6. Role of the Teacher	He/she will follow your activities on a daily basis. 1. He/she will monitor the work of the community of students, intervening if they encounter difficulties that they are not be able to solve in time. 2. At the end of the week, the teacher will deposit feedback on the process followed by the group.
7.Schedule and Time	Show the total elapsed time allowed for the e-activity. Give the deadline. Estimate the total study time required.
8. Next	Link to the next e-activity For example: – A self-assessment activity **(See below**) or – A game (The games in the platform)
9. (Formal) Assessment methods	**Execution of planned activities:** Implementation of the activities Respect of the deadlines **Output quality** Congruence and relevance of individual and group products with the indicated criteria Degree of innovativeness/originality of the product Process: The global number of messages exchanged Number of messages posted by each member Identification of procedures for group work Any individual or group difficulties

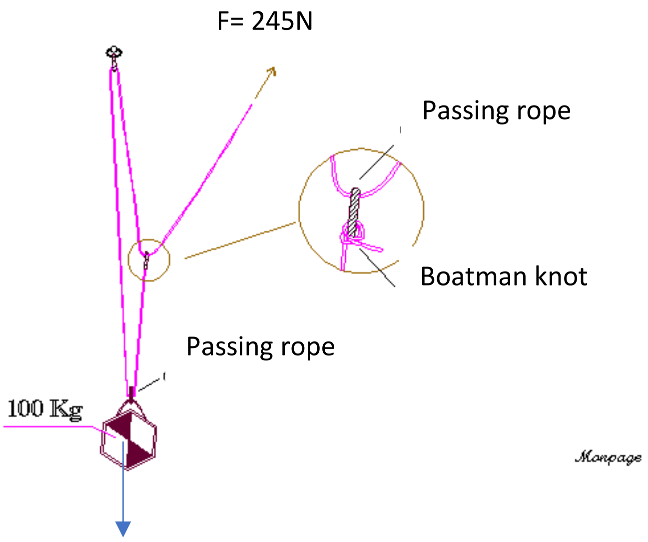
APPLICATION OF THE 9-STEPS DESIGN

in order to design a course on pulleys

GROUP OF ITALIAN EXPERTS

This activity was carried out remotely using the Google classroom platform, after having carried out the laboratory on the pulleys in presence (see worksheet on pulleys). It requires students to build a hoist, to use it to lift weights, to understand how it works and understand the similarities between the hoist and the fixed and mobile pulleys they have already used in the physics lab at school. Students need simple materials that are readily available at home and will have to upload photos of the hoist built and / or short videos on its use on the Google classroom platform.

STEP	DESCRIPTION
1. Title	**Forces on the mountains:** From the simple hoist to the mobile pulley.
2. Purpose	**The activity will allow you to:** Build a simple hoist, use it to lift weights, understand how it works and identify the forces involved. **Essential ideas: weight force, tension of a rope, decomposition of forces, resultant of forces and balance of forces, gain in strength, work of a force.** This activity is proposed after introducing the functioning of the fixed and mobile pulleys to the class and after the laboratory activity on the pulleys (see worksheet on the tension of a rope, fixed pulley and mobile pulley) The study of the forces involved, the gain in strength and the loss in displacement obtained with the hoist should lead students to make an analogy between the hoist and the mobile pulley.
3. Task overview	**The activity will allow you to:** 1. Build a simple hoist, 2. Use it to lift weights, 3. Understand how it works 4. Identify the forces involved.
4. Motivation	Collect images and videos where the hoist is used to lift weights up a mountain or during construction works. Recovery from crevasse or rock **https://www.youtube.com/watch?v=_R6ClLx7cHA** **https://digilander.libero.it/monpage/Paranchi.html**

STEP	DESCRIPTION
5. Participants tasks	**Now you're ready to build a simple hoist, to observe and describe how it works.** 1. Build the hoist shown in the figure:  2. Load the hoist built with masses you have at home (a pack of pasta, a kilo of sugar, etc.). Lift the load. **What do you notice?** Answer the following questions with complete sentences: 3. Explain why in the figure a mass of 100 kg is balanced by a force of about 245 N? 4. (Ignore friction and assume all forces to be vertical) 5. Draw the force diagram 6. What is the tension of the rope? 7. The force F that keeps the weight P in equilibrium is P / 4. 8. Ignore friction and assume all forces to be vertical. Why? a. What is the mechanical advantage of using the hoist to lift a weight? Why? b. Compare the hoist with the mobile pulley by identifying similarities and differences c. If you pull the rope 40 cm how much is the weight lifted? Why? d. What can you deduce from this latest result? – **Exchange your findings in the community.** *Design an experiment with the materials you have at home to test that F=P/4 (question 5)* *Make a video of the experiment and upload it to the platform* – **Discuss with the students of your team your answers.** *Finally, write your experimental report. The report must contain the answers to the questions asked. Upload the report to the platform.*

STEP	DESCRIPTION
6. Role of the Teacher **The intervention of the teacher will be through thought provoking questions.**	He/she will follow your activities on a daily basis. 1. He/she will monitor the work of the community of students, intervening if they encounter difficulties that they are not be able to solve in time. 2. At the end of the week, the teacher will deposit feedback on the process followed by the group. **This activity is autonomous and experimental, the teacher eventually answers the students' technical questions.** **Example of guiding questions and/or tips** 1. Identify in the hoist experiment the load and the effort. 2. Identify the displacement of the load and the corresponding displacement of the force. Determine their relationship 3. If, in your experiment, the force F that keeps the weight P in equilibrium is not P / 4 what other force, that we have neglected, is acting? 4. Why? 5. How does this force affect the mechanical advantage of the hoist? Why? 6. This force (frictional force) also acts if we replace the hoist ring (passing rope) with a mobile pulley. 7. Is the friction greater by using the hoist shown in the figure or a mobile pulley instead of the passing rope ring? Why? Justify your answer
7.Schedule and Time	Show the total elapsed time allowed for the e-activity. Give the deadline. Estimate the total study time required. Three online lessons: one, about 30 minutes, to present the activity; one, about 45 minutes, to guide students in difficulty, one of about 60 minutes to correct the activity and share the results obtained. Students have a minimum of one week to perform the experiment and submit their reports and videos
8. Next	Link to the next e-activity For example: – Compare the hoist with the mobile pulley systems by identifying similarities and differences – Reflect on the role of friction (answer: Does the presence of friction alter the expected results? – In-depth study of the role of friction – A game (The pulley games in the platform)
9. Formative Assessment	**Execution of planned activities:** Implementation of the activities Respect of the deadlines **Output quality** Congruence and relevance of individual and group products with the indicated criteria Degree of innovativeness/originality of the product **Process:** The global number of messages exchanged Number of messages posted by each member

	Identification of procedures for group work Any individual or group difficulties

GROUP OF GREEK EXPERTS

TITLE: CAN YOU LIFT A PROFABRICATED HOUSE?

B: SUBJECT

Physics, mechanics, displacement, force, work, potential energy, simple machine (pulley).

C: LEVEL OF EDUCATION

First class of high school

D: DURATION

3 hours

E. PURPOSE

The students will:

Recognize the forces acting on a pulley in order to lift a load

Measure the applied force and work needed to lift a load as well the potential energy

Invent the advantage of using pulley (generally a simple machine) in order to lift a heavy body as a prefabricated house.

F. TASK OVERVIEW

The activity will allow students to:

1. Use a pulley simulation,
2. Understand how it works
3. Use it to lift weights
4. Compare the applied force to the load's weight
5. Measure the work of the input force and the potential energy of the lifted body
6. Recognize the different kinds of pulleys
7. Understand the main advantage of using pulleys

G. MOTIVATION

Can you imagine why that factory has installed this instrument under the ceiling?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

How we call this machine?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

H. ROLE OF THE TEACHER

1. The teacher is a facilitator, help students to proceed the experiment, encourage them to communicate and skip any difficulties with the specific simulation.
2. The intervention of the teacher will be through provoking questions such as:
    - Do you know any simple machine?
    - Have you ever seen or used a simple machine?
    - What is the difference between a machine and a simple machine?
    - A pulley is a simple machine. Can you tell me an example of using a pulley in your real life?
    - Identify the load and the effort.
    - Compare the effort with and without the pulley.
3. The teacher shows the total elapsed time allowed for the e-activity, give the deadline, estimate the total study time required.
4. At the end, the teacher will discuss with the students and deposit feedback by asking:
    - Pulleys reduce the body weight in order to be easier to lift it or not?
    - Is it possible to change the direction of our force acting on a body?
    - A simple machine makes our life easier. What do we mean by saying this?
    - What is the main advantage of using a pulley? It has to do about forces or energy?
    - What makes a single fixed pulley different from other simple machines?

I. PARTICIPANTS TASK

Students work in groups, with worksheets and they use computers with internet connection. They communicate each other by using suitable platform or / and chat application such as sisco webex meeting or Microsoft teams or zoom.
To do the experiment, the students will use the pulley simulation, in Pulley Simulation 1.3 (compassproject.net).

WORKSHEET

The problem

When we use pulleys to lift a heavy object what is the main advantage? We need less force, less energy or both? Try to explain

……

……

Experiment

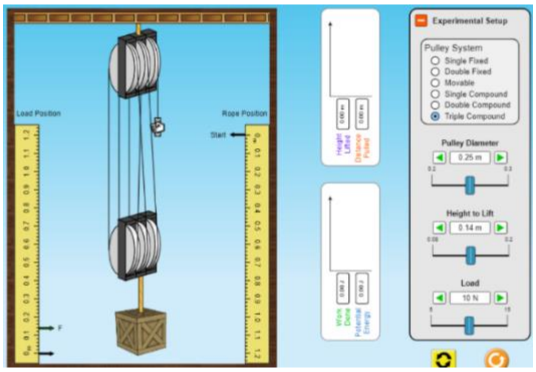
In order to check your answer above, you can do the experiment with the pulley simulation in Pulley Simulation 1.3 (compassproject.net)

The lifted load and the height will be stable

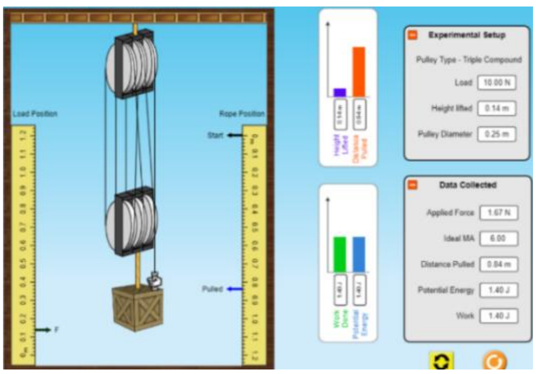
You will measure the applied force, the work and the potential energy for each pulley in order to lift a specific load to a specific height.

Software environment

Step 1: Open the software by clicking on the link: Pulley Simulation 1.3 (compassproject.net) Your screen will be as above.



When you begin the measurements, the screen changes as above



Measurements

Set the Load to 10N and the height to lift to 0.14 m.

Step 2: Choose on the Pulley System the single fixed pulley and increase slowly the applied force in order to manage to lift the load. Fill the first line of the table above

TABLE

Pulley	Does the direction of the applied force change by using this pulley? YES/NO	Applied force (N)	Height lifted h (m)	Distance pulled Δχ (m)	Work (J)	Potential Energy (J)
Single fixed			0.14			
Single movable			0.14			
Single compound			0.14			

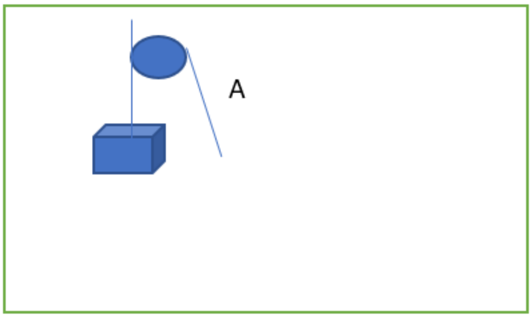
STEP 3: Choose on the Pulley System the single movable pulley and increase slowly the applied force in order to manage to lift the load. Fill the second line of the table.

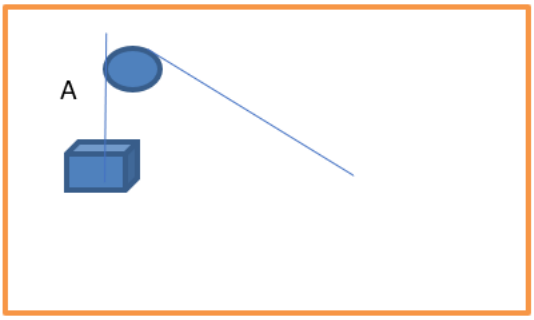
STEP 4: Choose on the Pulley System the single compound pulley and increase slowly the applied force in order to manage to lift the load. Fill the third line of the table.

RESULTS

<u>According to the measurements of the table, answer the following questions:</u>

1. You want to lift a weight of 10N with your own hands. How many Newtons will be your force? ………………… Which will be the direction of your force? ……………………………………………………………………………………………………
2. Draw the body's weight and the applied force at the end of the rope (point A) in order to lift the object.





1. What is the main advantage of using the single fixed pulley?
………
………
………
………
2. What is the main advantage of using the single moveable or compound pulley?
………
………
………
………
3. When we use pulleys in order to need less force to lift a heavy object, is there anything we lose?
………
………
………
………
4. When we lift a specific object to a specific height, its potential energy of the body depends on the pulley we use or not? Explain
………
………
………
………
5. When we use pulleys to lift an object to a specific height, we need less work or not? Explain
………
………
………
………
6. Does the pulley's diameter affect anything of the above? Check your opinion by using the simulation.
………
………
………
………
7. Simple machines are pulleys, inclined planes, levers and gears. When we say that simple machines make our life easier, what do we mean?
………
………
………
………

8. You want to lift a heavy body of 1000N weight and your applied force can be under 250N. Design a pulley's system to be able to lift the object.

9. Calculate the applied force in the specific mechanical system you have just designed.
………
………
………
………

10. During a walk along the seaside, you see this simple machine under the entrance to a yacht. Can you explain the reason for being there and how it works?
…………………………………………………………………………………………………
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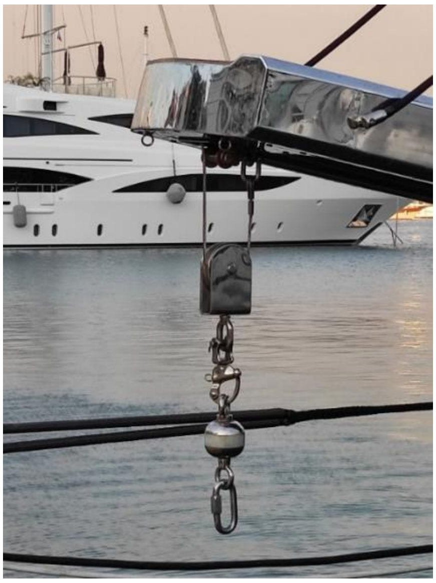

J. NEXT

1. Scan your worksheet, make it pdf and send it by email to your teacher.
2. Connect to the link: www.stemap.eu/games, choose pulley and play the game.

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IN A NUTSHEL

(i) Before the course begins...

Technical Aspects

- Make students familiar with the course management system and how to use specific features including how to post content, editing and reordering, news announcements, adding or rearranging discussion prompts, etc.
- Review all external links to learning resources to ensure they are not outdated or broken. Make sure to remove dead links.
- Include information about whom to contact for technical assistance.

Course Organization

- Create a course calendar that clearly outlines due dates.
- Inform students about communication method, expected response times to email messages, and expected response time for feedback on assignments.
- Establish rules concerning how to participate in online discussion forums.

(ii) During the course...

- Watch out for non-participants during the first week of class and contact them to see if they have login/access difficulties.
- Encourage students to post a photo or other representation (avatar) on their student profile.
- Communicate regularly through announcements.
- Monitor the discussion/forum area daily. Provide positive feedback (personally) to those who nurture the discussion area with their participation.
- Participate in discussions when appropriate. Know when to be the "guide on the side" and when to step in and redirect or supplement or summarize student participation.

Remind students of upcoming deadlines.

Online Trainee Satisfaction

- How satisfied are you with your online course?
  Very satisfied - Satisfied - Neutral Dissatisfied - Very dissatisfied
- Have you taken an online course before?
  Yes No
- I found access to the course material flexible and convenient
  Yes No

- Please indicate your level of agreement with the following statement: “The online course was easy to navigate.”
  Strongly agree- Agree -Neither agree or disagree -Disagree -Strongly Disagree
- The workload for the online activities was manageable
  Yes No
- Please indicate your level of agreement with the following statement: “The online activities made studying the course interesting and engaging”
  Strongly agree -Agree -Neither agree or disagree –Disagree- Strongly Disagree
- How satisfied are you with the trainee support services (technical support) associated with your online course?
  Very satisfied -Satisfied -Neutral Dissatisfied- Very dissatisfied
- Please indicate the level of agreement with the following statement: “I would recommend this online course to my colleagues”
  Strongly agree -Agree -Neither agree or disagree -Disagree Strongly

Annex 1 – Worksheets

GEAR:
www.stemap.eu/gear

GEARS

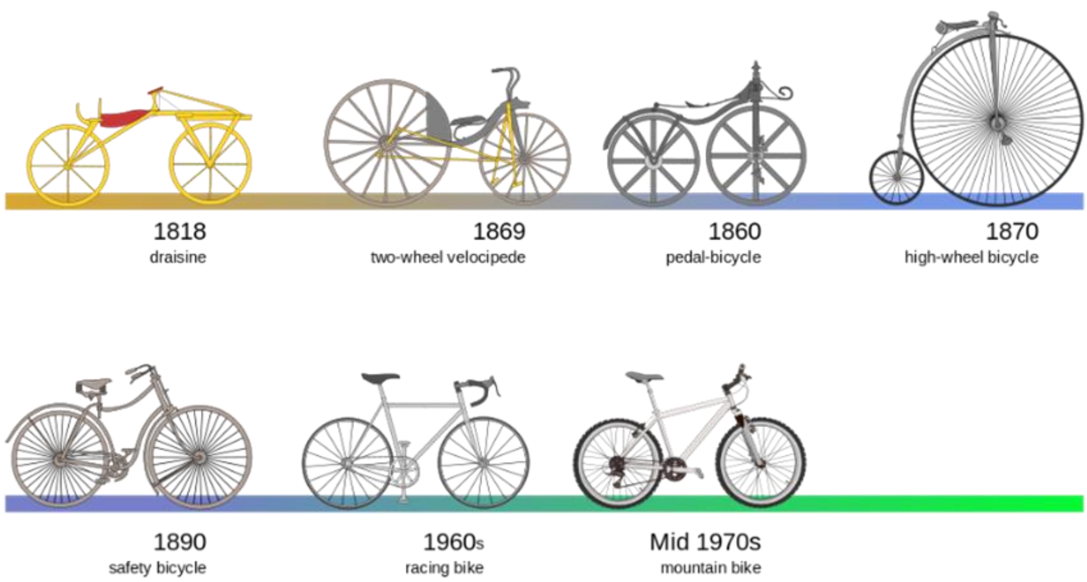
Name: ………………………………………………………………………………………… Date: …………..
School: ……………………………………………………………………………………… Class: ……………

Before the experiments

QUESTIONS BEFORE THE EXPERIMENTS

Answer the questions related to the Gears:

- What is a spur gear?
- Why does a bike have gears of different sizes?
- Gears are all around us. Give examples of where you might see Gears working.
- Explain what the advantage of using a Gear is!
- Whether is there any condition for the two gears to fit gearing?
- Which is the driver gear if you need to slow down motion?
- What can you say about linear velocity of the tooth if the 2 gears in a system are different size?
- What can you say about number of revolutions of the 2 meshing gears if they are different size?
- What directions do the two gears in a system rotate? How can you make the driver gear and driven gear rotate both clockwise?
- Exploring bikes



It is possible to travel three times faster by bike than walk, besides consuming the same amount of energy. For the simplest bicycles, two gears connected by a chain provide movement.

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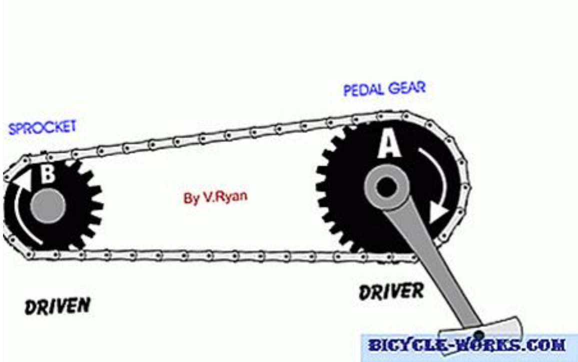
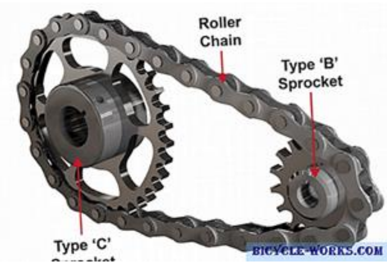
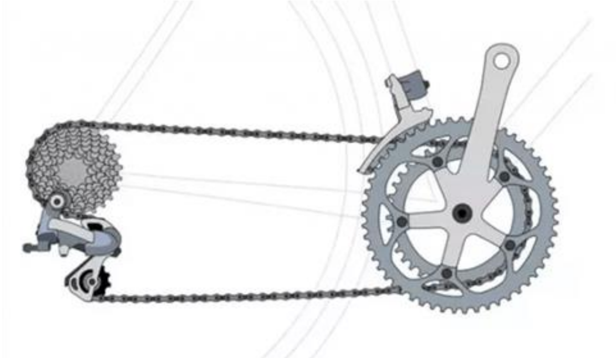
Il punto di incontro dei giovani con l'Europa





1. Why do you need two gears?
2. How does such a gear system work?
3. Where is it comfortable to ride on this type of bike? / Which road is comfortable to ride on this type of bike?

Most bikes are equipped with a shifting gear system. It works by a system of gears and mechanisms that move the chain between gears with different numbers of teeth.



4. What is the purpose of variable gear?
5. What effect does the cyclist feel when switching?
6. How the choice of gear (lower or higher) is influenced by weather conditions:
   - • headwind,
   - • type of road surface (e.g. sand),
   - • terrain changes (mountain ride)
   - • terrain changes (downhill)
7. One of the most popular bikes MTB (Mountain Terrain Bike) is equipped with a large number of gear changes (21 - 30). Explain why?

Experiment 1

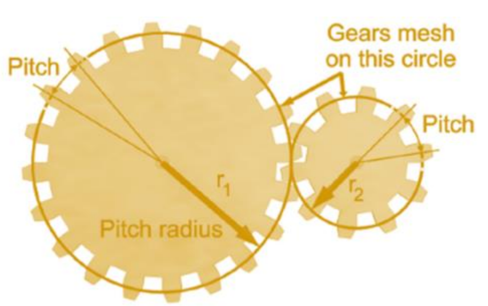
TITLE: Zobrata soļa noteikšana GEAR PITCH

FOR THE TEACHER

Before the experiments students must be taught the information provided below.

The gear set is characterized by 3 values:

- **Number of teeth, n**
- **Pitch radius, r**: The pitch radius is the radius that passes through the points where two gears mesh. This circle is called the pitch circle and the pitch circles of two connected gears meet at a single point.
- **Pitch, p**: the pitch is the distance around the pitch circle between the same two points on two adjacent teeth.



During laboratory work, students conclude that a pair of gears may have different radii to gearing but must have the same tooth pitch.

Formulas for calculating circumference $c = 2\pi r$ of teeth

$p = \frac{2\pi R}{n}$ should be applied.

LAB SHEET

Introduction

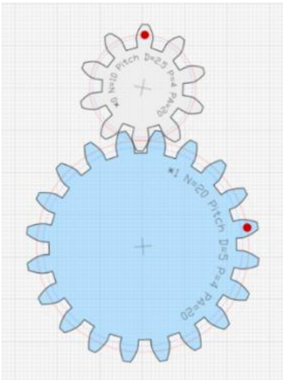
The aim of the laboratory work is to find out what is the regularity between the distances between the two tooth centers of the teeth. *Laboratorijas darba mērķis ir noskaidrot, kāda likumsakarība pastāv starp sazobē esošu divu zobratu zobu centru attālumiem.*

Equipment

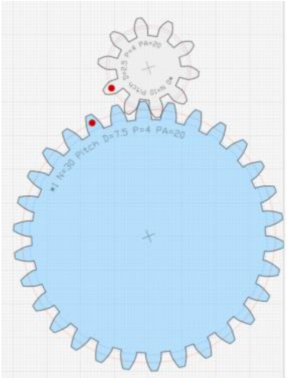
3 or more different sets of gears, ruler, caliper.

Procedure:

There are given three different gear sets.



1.



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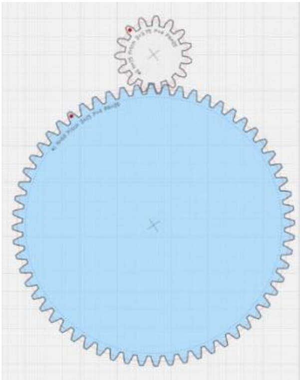


3.

For each gear set:

- Measure the radius of each gear R1 and R2.
- Calculate the circumference of each gear C1 and C2.
- Count the number (n) of teeth and calculate the length of arch between the centers of two adjacent teeth p1 and p2.

Table of results:

Gear set	R1	R2	C1	C2	P1	P2
1.						
2.						
3.						

Calculation:

What regularities did you see?

FIX CONCEPTS AND REFLECTIONS

Check your answers to the question V before the experiments. What are your conclusions?

Experiment 2

TITLE: Zobratu sistēmas zobu skaita un apgrieziena skaita attiecības RELATION OF TEETH AND REVOLUTION OF GEAR SET

FOR THE TEACHER

During the experiment, students have to come to conclusion that there is inversely proportion between the numbers of teeth of the gears to their number of revolutions.

LAB SHEET

Introduction

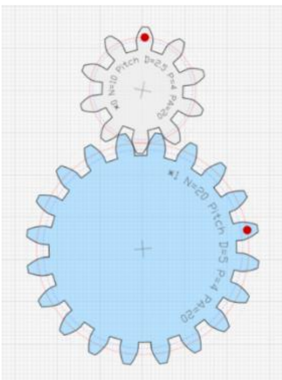
In each gear system, there are certain regularities between gear sizes, number of teeth and revolution.

Equipment

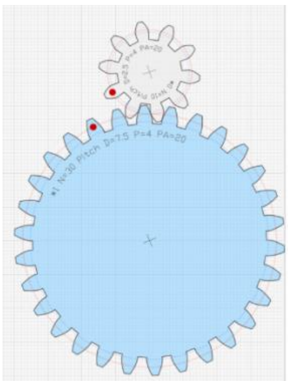
3 or more different sets of gears, ruler, caliper.

Procedure:

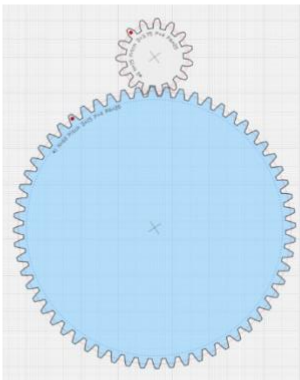
There are given three different gear sets.



1.



2.



3.

Investigate how these systems work. What regularities can you see?

Take dimension measurements of each gear pair and record them in the table: D1 – diameter of the smallest gear and D2 - the largest gear.

Calculate the gear diameter ratio D1: D2 and record them in the table.

In each system, for each of the gears, determine the number of teeth: N1 - the smallest gear and N2 - the largest gear, and record them in the table.

Calculate the ratio of the teeth number of gears N1: N2.

In each system, determine the mutual gear ratio n1: n2 (small gear revolutions: large gear revolutions), record in the table.

GEAR SET	Diameter of small gear (D_1)	Diameter og largs gear (D_2)	$D_1 : D_2$	Number of teeth	Number of teeth (large gear) (N_2)	$N_1: N_2$	$n_1 : n_2$

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				(small gear) (N_1)			
1.							
2.							
3.							

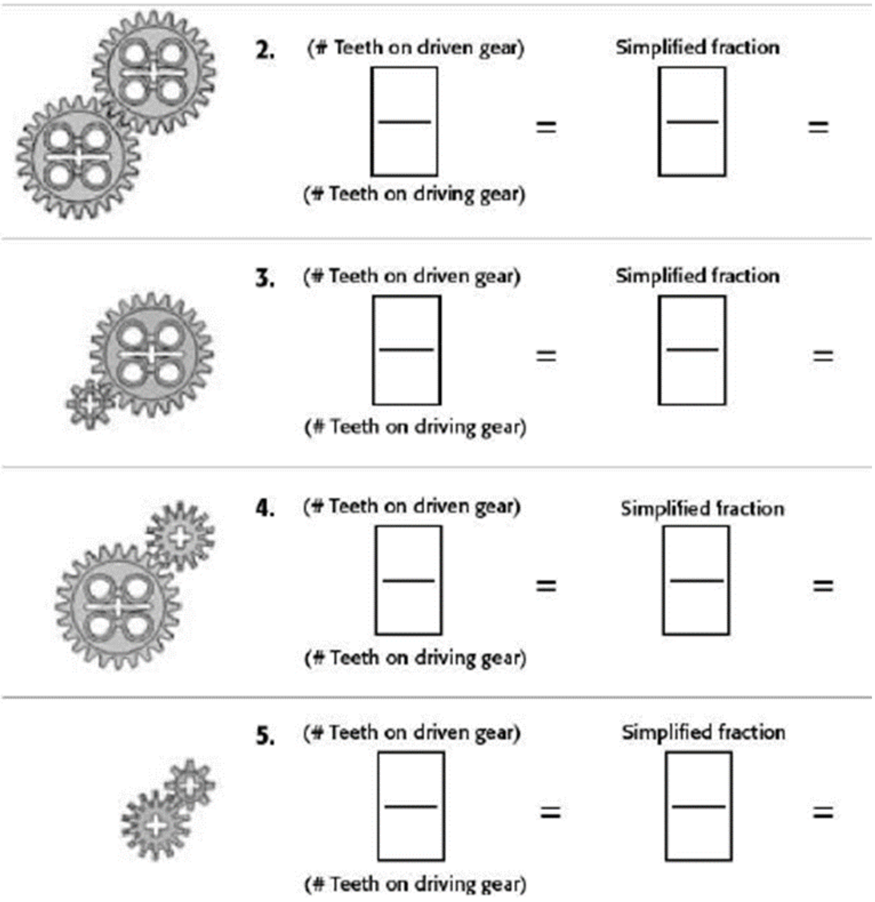
Calculations:

What regularities can you see? Think about the number of revolutions for each gear!

FIX CONCEPTS AND REFLECTIONS

Check your answers to the questions IV, VI-X before the experiments. What are your conclusions?

Activity:



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Experiment 3

TITLE: THREE MESHED GEARS

FOR THE TEACHER

During the experiment, students have to come to conclusion that the idler gear does have impact on gear ratio, the idler gear ensures that the driver and follower rotate in the same direction.

LAB SHEET

Introduction

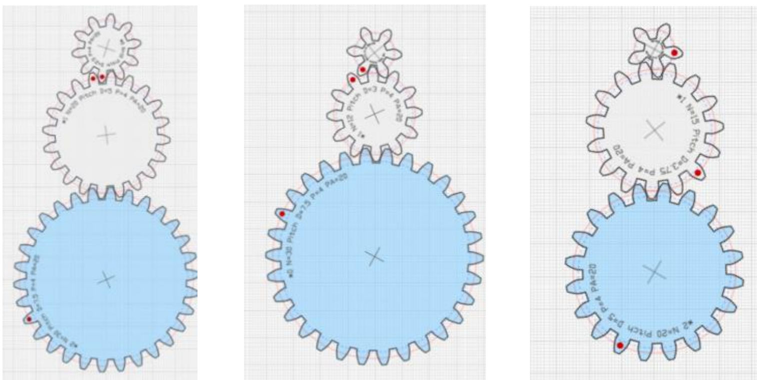
We have already found out that there are several relations between two meshing gears. It is time to find out what are the relations between 3 meshing gears.

Equipment

3 or more different sets of gears, ruler.

Procedure:

You have 3 different meshing gears systems. The upper gear is driver, and it rotates clockwise.



1. 2. 3.

Investigate how these systems work. What regularities can you see?

In each system

Determine the directions of rotation of the gears.

Determine the ratio of driver to idler gear n_1: n_2.

Determine the ratio of the idler and driven (third) gear n_2: n_3.

Determine the ratio of the driver and driven (third) gear n_1: n_3.

Table

GEAR SET	Direction of rotation driver gear	Direction of rotation idler gear	Direction of rotation driven gear	$n_1: n_2$	$n_2:n_3$	$n_1:n_3$
1.	clockwise					
2.	clockwise					
3.	clockwise					

Calculations:

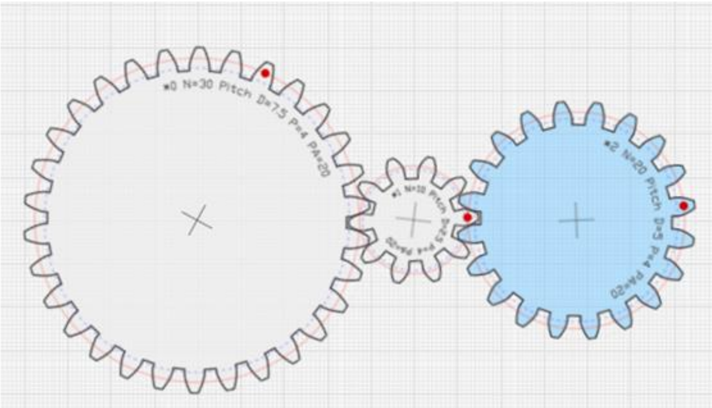
What are the regularities between the gear ratios?
What regularities can you observe between the directions of gear rotation?

CONCEPTS AND REFLECTIONS

Check your answers to the questions IX before the experiments.
Can you find a general relationship between the ratio of the turns of the first and last gears when there are many connected gears?

Activity:

Consider the following set of gears. The largest gear turns clockwise through one full turn. How many times will gear 3 turn and which direction? How does this compare with the previous result?



Experiment 4

TITLE: TWO IDLER GEARS ON THE SAME AXLE

FOR THE TEACHER

Regarding direction of rotation students have to conclude that matters odd or even number of axles, not odd or even number of gears.

LAB SHEET

Introduction

We have previously found out that there are several relations between two meshed gears and three meshed gears rotating in one plane.

Now let us find out what the relations are between the four gears arranged in two planes, and in each plane, there are two meshed gears, besides idler gears rotate on the same axle.

Equipment

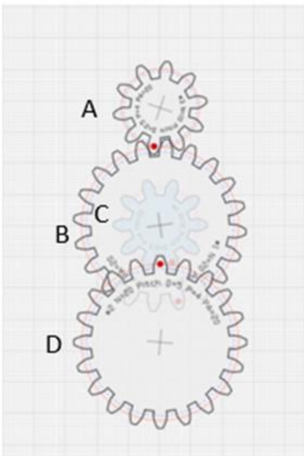
3 or more different four-gear systems in which gears B and C rotate on the same axle, at the same speed.

Procedure:

Investigate how these systems work. What regularities can you see?

For each system

- determine the gear ratio A and B of a gear in one plane N_A: N_B;
- determine the gear ratio C: D of the gear in the same plane N_C: N_D;
- determine the gear ratio of the side gears A and D of the system N_A: N_D.



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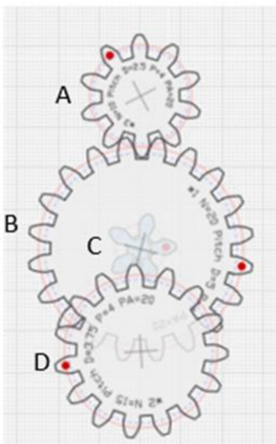

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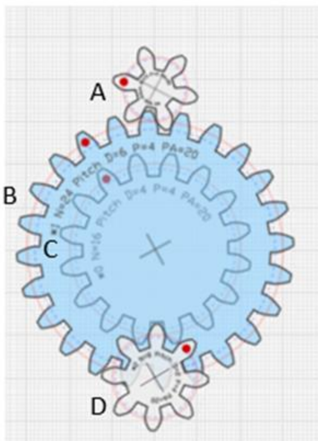

3.

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Gear system	$N_A : N_B$	$N_C : N_D$	$N_A : N_D$
1.			
2.			
3.			

Calculations:

What are the regularities between the speed ratios?
Explain what the dimensions of the gears and their position in the four-gear system placed in two planes should be in order to maximize the ratio between the side gears?

FIX CONCEPTS AND REFLECTIONS

- When determining gear direction is it the number of gears that matters or the number of gear axles?
- How does the placement of two gears of different radii on the same axle relate to the movement of the bicycle? Look back at your answers to question II and X before experiments!

Experiment 5

TITLE: DETERMING CHARACTERISTICS OF HIDDEN GEAR

FOR THE TEACHER

Students have to think about the linear and radial velocity of a point on a circle and use expressions of linear velocity and radial velocity.

As the gears are meshed, they have the same linear velocity ($v_l = v_m$)

$$v = \omega R \text{ and } \omega = \frac{\varphi}{t}$$

$$\omega_l R_l = \omega_m R_m$$

$$\frac{\varphi_l}{t} R_l = \frac{\varphi_m}{t} R_m \text{ (1.formula)}$$

As the small gear has gone through one full turn, then $\varphi_m = 2\pi$

In turn, the large gear φ_l corresponds to n teeth. If there is a full revolution, then the angle 2π corresponds to N. A proportion can be drawn

$$\frac{\varphi_l}{n} = \frac{2\pi}{N}, \text{ where } \varphi_l = \frac{2\pi n}{N}$$

By inserting the obtained relations (in formula 1)

$$\frac{2\pi n R_l}{N} = 2\pi R_m, \quad \text{from this we conclude} \quad R_m = R_l \frac{n}{N}$$

Since both gears have turned by the same number of teeth, counting n on the large gear gives the number of teeth of the small gear. ($n = n_m$).

LAB SHEET

Introduction

In this experiment, you have to think about the linear and radial velocity of a point on a circle. You have a set of meshed gears, where the smaller gear is hidden, you can see only few teeth of gear. One tooth is marked on each gear.

Tasks:

- Determine the number of teeth of the small gear.
- Determine the radius of the small gear.

Equipment

A set of meshed gears, ruler, calliper.

Procedure:

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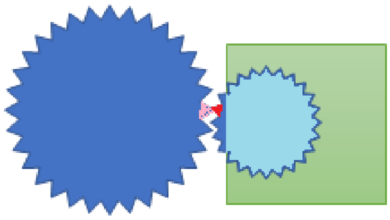

Picture 1


Picture 2

- The large gear is rotated until the marked tooth of the small gear is in the start position again.
- Count how many teeth the big gear has turned (n) while the small one has made a full turn.
- Count the number of teeth of the large gear N.
- Measure the radius of the large gear is R_l.
- Determine the number of teeth of the small gear.
- Determine the radius of the small gear R_m.

Table of results:

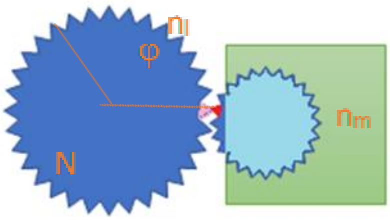
Nr.	n	N	R_l	R_m

Calculations:

Prove the result obtained using physics formulas!

FIX CONCEPTS AND REFLECTIONS

- Explain how you got the number of small gear teeth!



- What can you conclude about the linear speed of gears?

Reflection after all experiments:

What advantage do you gain from using gears? Check your answers to the question IV before the experiments.

INCLINED PLANE:
www.stemap.eu/inclined-plane

INCLINED PLANE

Name: ………………………………………………………………………………………… Date: …………..
School: ……………………………………………………………………………………. Class: ……………

Before the experiments

INITIAL QUESTIONS

Answer the following questions:

- What is an inclined plane?
- Where we find an inclined plane?
- What is the advantage of using an inclined plane?
- Draw an inclined plane and explain how it works.

QUESTIONS BEFORE THE EXPERIMENTS

- A car is held motionless on a ramp (ramp) with the help of a rope strapped to a dynamometer. **The same car** hangs vertically from a dynamometer. ***In which of the two cases is the dynamometer indicator greater?*** Explain <u>by detailing all the forces exerted on the car in both cases</u>.

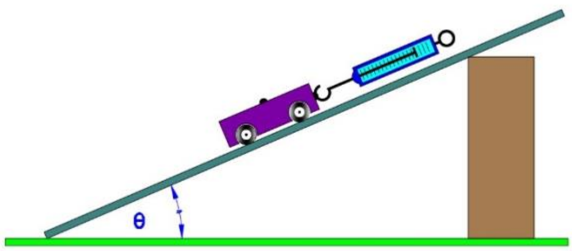


Figure 1

Figure 2

- In the previous question, does the strength that the dynamometer count depends on the angle of the ramp? Yes or no? Explain.
- If so, when the angle of inclination grows, what change do we expect to see in the dynamometer indicator?
- When a body is still (has zero velocity) on a ramp, how much the net force on the parallel axis with the ramp is? Zero or various of zero?.............................
- Is it easier to pull an object upwards on a ramp or lift it vertically? Explain
- Which parameter determines the size of the force required to pull an object up to a certain height using an inclined level? Explain.

- Suppose that one body moves upwards on a ramp at a constant speed. How much do you think the net force is? Zero or various zero?
- It's harder to lift an object than to decrease its height. Explain by using the concept of energy.
- In order to lift an object to a specific height we will have to transfer energy to the body. This energy will be different if we raise the body vertically or through an inclined plane? If yes, in which case should we transfer more energy?
- Let's suppose that we have two ramps with the same height but the second one has double length compared to the first. Which of the two ramps needs more energy to be raise the same object? Explain.

Experiments

EQUIPMENT

Inclined plane with a vehicle, two dynamometers, protractor, rope and measuring tape.

Experiment 1

TITLE: FORCES ALONG AN INCLINED PLANE

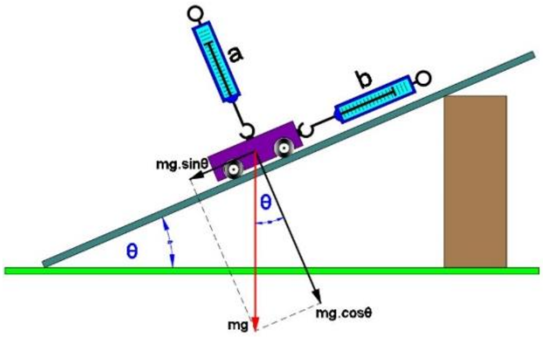
FOR THE TEACHER

Students will:
analyze the weight in two axes and calculate the parallel and vertical force to the ramp.
conclude that by using the inclined plane, they need less force in order to lift an object.
discover the relationship between the force needed and the angle of the inclined plane.

LAB SHEET

Procedure:

- Count the weight of the vehicle with a dynamometer w=mg =…………………



Picture 3

- Place the vehicle on the inclined plane with an angle of 15 degrees and connect it with the **dynamometers a and b** as presented in the picture 3. With the **dynamometer a** pull the vehicle so that the vehicle barely touches the inclined plane. When the body balances on the inclined plane take the indications of the dynamometers. The **dynamometer a** count the normal force **F_N** and the **dynamometer b** counts the parallel force on the inclined F_X. Repeat the experiment on different angles that appear on board 1 and fill in the blanks.

BOARD 1

Ramp's angle in degrees (A)	sinθ (B)	cosθ (C)	mgsinθ in N (D)	mgcosθ in N (E)	Parallel force F_x in N (F)	Normal force F_N in N (G)
15	0,26	0.96				
30	0,50	0.87				
45	0,71	0.71				
60	0,87	0.50				
75	0,96	0.26				

- Make a diagram from the values of board 1 in which the x axis will have the angle of inclination and in the y axis will have the parallel force on the inclined plane. What do you observe? Which is the relation between the angle of inclination and the indication of the dynamometer b?
- Which will be the indication of the dynamometer b when the angle of inclination becomes 0 or 90 degrees?
- Compare your results of the column (F) on board 1 with the weight of the vehicle. What do you observe?
- Compare the results of columns (D) and (F) on board 1. What conclusion do you draw about the net force parallel to the inclined plane?
- Compare the results of columns (E) and (G) on board 1. What conclusion do you draw about the net force vertically to the inclined plane?
- Check your answers to the questions 1 to 4 according to board 1. Which are your conclusions?
  - Question 1
  - Question 2
  - Question 3
  - Question 4
- Which one do you think is the main advantage of the use of the inclined plane?

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Experiment 2

TITLE: MECHANICAL ADVANTAGES – WORK – ENERGY

FOR THE TEACHER

Students will conclude that when we lift an object in a specific height, the work needed is the same, either we lift it vertically or by using the inclined plane. This has to do with the gravitational potential energy.
Students will calculate the mechanical advantages in different angles.
In this way, they will acknowledge the advantages of using a simple machine in real life.

LAB SHEET

Definition of the mechanical advantages

The division of the weight (load) that we will lift to the force we act is called **actual mechanical advantage** of the inclined plane:

$$\text{A.M.A.}=\frac{\text{Weight(load)}\,we\ lift}{\text{Force}}=\frac{\text{mg}}{\text{F}\chi}$$

The division of the displacement of the acting force to the vertical displacement of the load is called **ideal mechanical advantage** of the inclined plane and depends on ramp's dimensions.

$$\text{I.M.A.}=\frac{\text{displacement}}{\text{vertical displacement of the load}}=\frac{S}{\text{h}}$$

Procedure

- Use the same vehicle. w=mg =…………………
- Place the vehicle on the base of the inclined level with a 15 degrees angle and connect it with a dynamometer parallel to the inclined so that you drag the vehicle upwards with your hand. (Figure 4) You have to lift the vehicle in height of h=0.40 m with constant velocity. The vehicle will move S meters on the inclined level. Slowly pull the vehicle so that the indication of the dynamometer will be stable. Repeat the experiment on different angles that appear on board 2 and fill in the gaps.

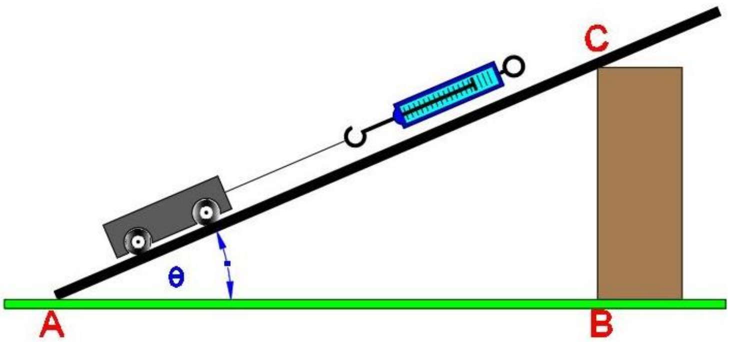

Figure 4

BOARD 2

Ramp's angle in degrees (A)	sinθ (B)	mg sinθ in N (C)	F_x in N *(D)*	Displacement S in m (E)	F_x* S in J (F)	A.M.A. mg/F_x (G)	I.M.A. S/h (H)
15	0,26						
30	0,50						
45	0,71						
60	0,87						
75	0,96						

- Draw in detail all the forces exerted on the vehicle in the case of experiment 2. Is there any difference between the design of forces in Experiments 1 and 2?
- Compare the results of columns (C) and (D) of Board 2. What do you draw about the net force parallel to the ramp when the body moves at constant velocity?
- Check your answers to the questions 5 to 7 according to board 2. Which are your conclusions?
  - Question 5
  - Question 6
  - Question 7
- In column F of board 2 you calculated the product between the input force and the vehicle's displacement. What happens to this product as the inclination angle of the inclined layer changes? What do you make of it?
- Compare the ideal mechanical advantage (I.M.A.) and the actual mechanical advantage (A.M.A.). What do you observe? Explain.
- When the inclination angle of the ramp is 30 degrees the s distance we move the vehicle on the ramp is .... times the height we want to raise the body. Then the force we attract the vehicle is .... times less than the weight of the vehicle.
- By using an inclined plane we have a mechanical advantage. What does mechanical advantage mean? What do we gain and what do we lose?
- You want to choose a ramp for your school so that it can climb at a steady speed α wheel chair with a traction force of 1/20 the weight of the wheel chair and rider. What should be the ratio of the height of the ramp to the length of the ramp? Explain.

Work and energy

Work of constant force

If an object undergoes a displacement S under the action of a constant force F, the work done is: **W = F S cosθ,** θ is the angle between the force and the displacement.

Work is a scalar quantity, and its unit is Joule (J). (1Joule=1N m).

Work is an energy transfer. If energy is transferred to the object, W is positive. If energy is transferred from the system, W is negative.

If vectors F and S have the same direction, θ= 0^o and cosθ =1 . Then: **W=F*S**

If vectors F and S have opposite directions, θ= 180^o and cosθ =-1 . Then: **W=-F*S**

If vectors F and S have perpendicular the same direction, $\theta = 90^o$ and $\cos\theta = 01$. Then: **W=0**

Gravitational potential energy

To lift a body we need work. When we lift a body with weight mg to height h, we transfer to it energy equal to **mgh**. We call this product gravitational potential energy. Then:

$$U = mgh$$

Gravitational potential energy is a scalar quantity, and its unit is Joule (J). (1Joule=1N m).

From board 2, calculate the work and the potential energy and fill the board 3.

BOARD 3

Ramp's angle in degrees (A)	Human's force work to lift the object by using inclined plane at height h=0.40 m $W=F_X*S$ in J (B)	Gravitational potential energy U=mgh at height h=0.40 m in J (C)
15		
30		
45		
60		
75		

According to the board 3 answer the following questions:

- What do you notice about the work in different angles?
- Compare the work of the human's force to the gravitational potential energy. What do you make of it?
- From columns D, E and F of board 2 we observe that when the ramp's angle decreases, the indicator of the dynamometer ………………………., the displacement of the vehicle ……………………………. But the product remains …………………………………. So when we gain in ……………………………… we lose in …………………………………………
- Check your answers to the questions 8 to 10 according to board 3. Which are your conclusions?
    - Question 8
    - Question 9
    - Question 10
- Explain why a road that goes up a mountain cannot go straight up and must have a lot of turns. What do we gain and lose by building roads in this way?

LEVER:
www.stemap .eu/lever-2-2

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LEVER

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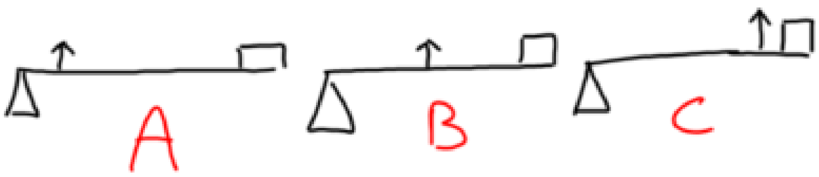
School: ……………………………………………………………………………………. Class: ……………

Before the experiments

QUESTIONS BEFORE THE EXPERIMENTS

Answer the questions related to the Simple Machine:

- What is a lever?
- Levers are all around us. Give examples of where you might see levers working.
- Explain what is the advantage of using a levers?
  - Which of the levers would be the easiest to lift the load?



- **Levers make-work** harder or easier? Explain

Experiment 1

TITLE: Bilateral lever balance condition

FOR THE TEACHER

The aim of the experiment is to determine the equilibrium condition of the bilateral lever.

LAB SHEET

Equipment

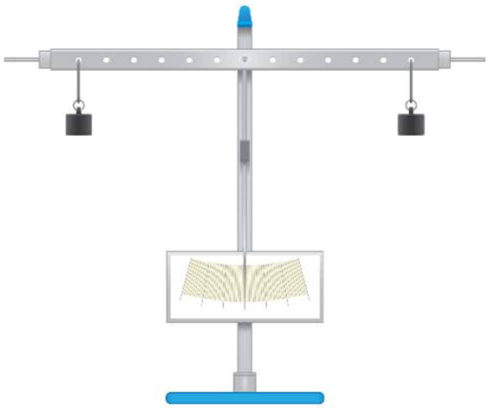
What you will need:

- a school model of a two-sided lever or a bar, a simple stick, a stick, a plastic rod about 30 cm long You can also use a cardboard tube with food foil wrapped around it. It is important that the element is not too smooth and has the same diameter along its entire length
- three pieces of string or strong thread - they should not be too smooth (slippery);
- ruler;
- ten equal weights. Instead of them, you can use large candies in wrappers, to which we will tie loops of thread. If we divide the total weight of candies by the number of candies, we determine the weight of a single candy.

Procedure:

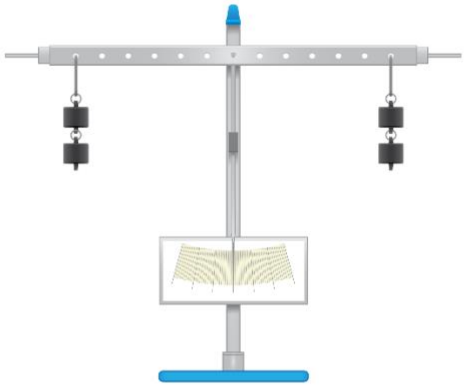
Attach the lever to a tripod.

If you are using a lever that you made yourself - mark its center, then on each side six two-centimeter sections, counting from the center. Tie a string in the middle of the slat and hang it on the stand. A view of a typical school lever is shown in the figure.

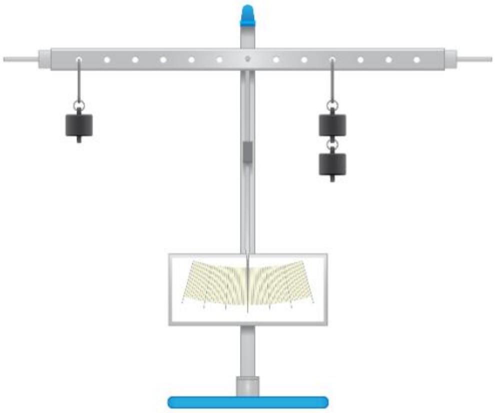


On the left side of the lever on the sixth On the left side of the lever on the sixth marker (counting from the center), hang one weight.

Choose the number of weights that you need to hang on the right side at the same distance from the center so that the lever remains balanced (the bar remains horizontal).



Select the number of weights you need to hang on the right side of the third marker, counting from the center, so that the lever remains balanced (the bar is hanging horizontally).



Select the number of weights that you need to hang on the right side of the second marker, counting from the center, so that the lever remains balanced (the bar hangs horizontally).
On the left side of the lever, hang the four weights on the fifth marker from the center.
Choose the number of weights that you need to hang on the right side of the fourth marker from the center so that the lever remains balanced (the bar is hanging horizontally).

Measurement table for experience									
Left side					Right-hand side				
Number of weights	Weight of weights m[kg]m[kg]	Force of gravity F[N]F[N]	Distance from the axis of rotation r[cm]r[cm]	The product F·rF-r [N·cm][N-cm]	Number of weights	Weight of weights m[kg]m[kg]	Force of gravity F[N]F[N]	Distance from the axis of rotation r[cm]r[cm]	The product F·rF-r [N·cm][N-cm]

Complete the table by calculating:

- weight (mm = weight of one weight x number of weights), remember to express it in kilograms;
- gravity of the weights, using the formula F=m·gF=m-g;
- the product of the gravity and the distance of the suspension point of the weights from the axis of rotation of the lever.

FIX CONCEPTS AND REFLECTIONS

Summary

The observations show that the lever remains in equilibrium even when the forces applied on both sides of the axis of rotation are not the same.

The lever remains in equilibrium when the forces applied on both sides of the axis of rotation have the same direction and sense (action of one of them tries to turn the lever clockwise and the other - counterclockwise) and the product of the values of the forces and arms of these forces is the same both sides of the axis of rotation. We can write this conclusion by the formula: FL· rL = FP· rP. This condition is true for forces perpendicular to the lever, but this is what we were dealing with when the lever was in equilibrium.

Remember!

The double-sided lever remains in equilibrium if the product of the force and the force arm has the same value on both sides of the lever support point, that is:

F1· r1 = F2· r2

and the forces on both sides of the axis of rotation have the same sense and are perpendicular to the lever.

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Experiment 2

TITLE: Determination of body weight with a two-sided lever.

LAB SHEET

Introduction

This experiment aims to determinate body weight with a two-sided lever, another body of known weight and a ruler.

Equipment

What you will need:

- a school model of a two-sided lever or a simple stick, a stick, a plastic rod about 30 cm long. You can also use a cardboard tube on which food foil was wound - it is important that the element is not too smooth and has the same diameter along the entire length;
- three pieces of string or strong thread (they should not be too smooth or slippery);
- two small, identical foil bags;
- ruler;
- a weight or other object of known weight - it can be a bag of pudding or a chocolate bar, the weight of which is indicated on the packaging (we will also call this item a weight);
- item to be weighed - for example, a pencil case.

Procedure:

In the middle of the stick, tie a piece of string tightly enough so that the stick does not slide out by itself, but loosely enough to move it around.

Grab the string, pick up the stick, check that it is hanging horizontally, and if not, move the string a little and check the balance - keep doing this until it is perfectly level. Mark the position of the string where the stick hangs horizontally.

Tie a piece of string with a loop at the end of each plastic bag. The loops must be large enough to be easily slipped over the ends of the stick. These are our scale dishes.

Put the weight in one pan and the weighing object in the other, hang the weighing pan at the ends of the stick and carefully start lifting the balance by the middle string.

If the balance tilts to one side, move the weighing pan on that side closer to the center. Try to keep the weighing pan containing the lighter object hanging almost to the end of the stick. Check that the weight you lifted is in balance. If not, repeat the movement of the heavier object until it is balanced.

When the dishes are in such a place that the stick hanging on the middle string is balanced - mark the positions of the dishes.

Use a ruler to measure the distance from the center to the pan containing the weight and write down:

r1 = ... cm

Use a ruler to measure the distance from the center to the pan containing the weighing body and write down:

r2 = ... cm

Record the mass of the weight:

m1 = ... g

FIX CONCEPTS AND REFLECTIONS

Now we proceed to calculate the unknown weight of the weighed body. Let us denote it mx.

We know that our stick with the scales suspended on the central string was a two-sided lever, which means that at the moment of achieving balance, the following condition was met:

$$F1 \cdot r1 = F2 \cdot r2.$$

The forces F1 and F2 are the weights of items placed in the dishes, that is:

$$F1 = m1 \cdot g,\ F2 = mx \cdot g.$$

After substituting these forces in the equilibrium condition of the levers, we obtain the equation:

$$m1 \cdot g \cdot r1 = mx \cdot g \cdot r2\ /: g,\ m1 \cdot r1 = mx \cdot r2\ /: r2,$$

$$mx = m1 \cdot r1r2.$$

We substitute the data recorded during the measurements and calculate the mass of the object.

Experiment 3

TITLE: Plank as a one-sided lever

FOR THE TEACHER

The teacher must always mentally estimate the force needed to raise the board to do not expose the student to overload. For example, with a two-meter board on which three pupils (45 kg each) are standing at a distance of 20 cm from the end of the board, lifting force will be equivalent to 135 kg / 10 = 13.5 kg. You have to take care of the aggravating group it was moved as close as possible to the end of the board.

If we are not carrying out this experiment in the field, it is worth going to the corridor or to a room with enough free space. If we don't have one possibility, at least let's move the benches and chairs away. Students watching the measurements let's set it up so that in the event of loss of balance by people standing on the board, they fall in the arms of the observers and did not hit the furniture.

LAB SHEET

Equipment

- •pine board with a thickness of min. 25 mm, width approx. 25 cm and longer be equal to 2 m (preferably approx. 3 m); does not need to be planed;
- • any work gloves, they can be "vampires" (if the board is not planed);
- • a wooden bar, approx. 20 mm thick, approx. 20 mm wide and 25 cm long or a similar support (it can be a strip of hard polystyrene);
- • workshop tape measure, 3–5 m long, or a 2-meter-long ruler
- m. For didactic reasons, it is advisable that the ruler should be longer than the board (no then you have to measure the boards in sections; see notes).

Procedure:

- Students put the plank on the floor. They put a stand under one of its ends (such so that you can slip your fingers under the board).
- The teacher places 2-3 students on the plank, as close as possible to the end of the leaning on the floor.
- One student grabs the other end of the board (the supported one) and lifts it up without much effort up. Together with the students, the teacher indicates the axis of rotation and the arms of the resulting rotation single-sided lever way.
- The students measure the length of both lever arms with a tape measure. They assume that the weight of the group pupil weighers is placed in the center of the area occupied by their feet (the student-observer marks this place on the board with a marker pen).
- Students who stood on the board say how much they weigh. Everyone calculates together by what force the fourth student raised the board (the simplest version does not take into account the weight of the board).
- The teacher draws the students' attention to the fact that the length of the arms is always measured from the axis turnover, and that the student-sinkers lifted only slightly, while in the meantime it's over the planks were raised much higher.

- The students measure the height of the end of the board with a ruler (this can already be measured on the board unloaded) and the rise of the mid-point around which the incriminating students stood the lever.
- Using the formula for the work of both forces, everyone recalculates the value of the student's strength carrying a board. The result should be similar to the previous one.
- The experiment can be repeated by moving the incriminating students a little closer to the center the board (not too close - the force at the end of the board must not endanger the health of the lifting student) or by changing the number of students loading the board at the axis of rotation

FIX CONCEPTS AND REFLECTIONS

It should be emphasized that the length of the arms of each lever is always measured from the axis of rotation. With a one-sided lever, students struggle with this: they often measure distances from the axis to the point of application of the first force and then incorrectly from there to the point of application of the second force. To preserve the correct image of the measurements in memory students should measure the length of the board "at a time", so the ruler must be long enough. You can also use a more advanced variant of the calculations, including the weight of the board itself. It is not necessary to add up all the moments of strength. Just estimate the force needed to lift one end of the board as half the weight of the board (see: pickaxe and stone block experience) and add this fix. We calculate the weight of the board, assuming that the density of dry pine wood is approx. 500 kg / m³ (1 l has a mass of 0.5 kg, and 1 cm³ weighs 0.5 g). The volume of the board is calculated from the formula for the volume of the cuboid after taking appropriate measurements. By picking up the plank from the floor, the teacher can draw students' attention in the correct way lifting, without endangering the lower spine (which, by the way, also works like lever) to excessive load. We lift by using the thigh muscles while maintaining straight back, not bending down and straightening.

PULLEY: www.stemap.eu/pulley-2-2

PULLEYS

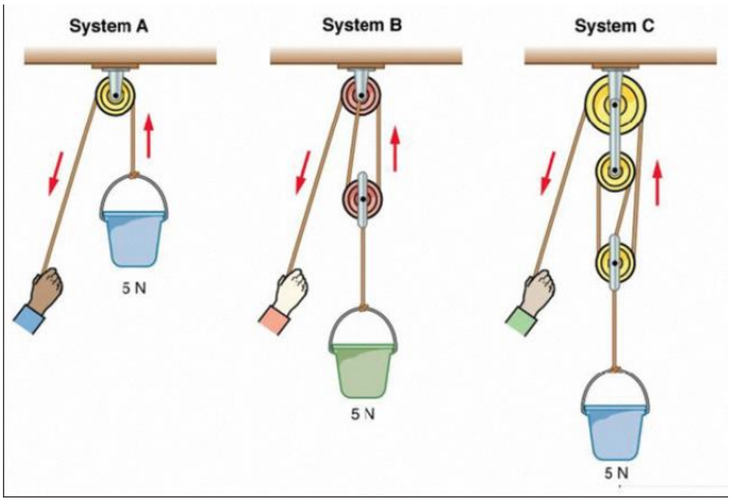
Name: ……………………………………………………………………………………… Date: …………..
School: ……………………………………………………………………………………… Class: ……………

Before the experiments

QUESTIONS BEFORE THE EXPERIMENTS

Answer the following questions:

- What is the tension of a rope? Is it a force? What is its direction? ….
- Can tension pull and push an object?
- What is a pulley?
- Where we find pulleys?
  - Pulleys are all around us. Give examples of where you might see pulleys working.
- Explain what is the advantage of using a pulley in the examples at the point IV?
- A one-wheel pulley allows the direction of a force to be changed.
- Why does the modulus force required and work done remain the same?
- In the figure below, which system needs the least force to lift the load?
-



- b) In which system do you move the load over the greatest distance?

EXPERIMENT 1

TITLE: THE TENSION ON A ROPE OR A STRING

FOR THE TEACHER

The experiment and the questions are intended to make it clear that, with certainty, the tension exerted on a block by a vertical wire has a vertical component, and that it's not possible to exert a horizontal force and move the block horizontally by a vertical wire, but we need to tilt the strand.

Students should conclude that the tension on a strand has always the same direction as the wire, and that it is not possible to point the tension in the opposite direction: if you lower your hand, the wire bends and you cannot exert a downward force on the mass. Tension can only pull on an object and not push it. This is because the wire is flexible and not a rigid rod.

By doubling the wire, the tension can be distributed on them.

Things get complicated if the body is suspended by two wires that form an angle with the vertical.

An elastic is a particular rope that stretches. When the elastic is at maximum tension it behaves like a rope.

The experiment, the discussion on the results obtained and the answers to the questions are intended to lead to the definition of the *ideal rope*.

An ideal rope:

- is perfectly flexible: the tension cannot have components perpendicular to the rope itself and it cannot push
- is inextensible: its length does not vary, regardless of its tension
- its mass is zero

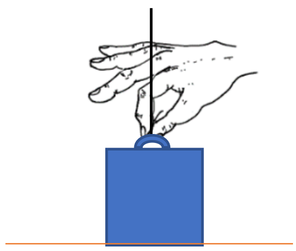
For ideal ropes, the tensions on either ends have the same magnitude but opposite direction. It is necessary to help students in thinking that the rope used in the experiment has much less mass than that of the block, that it is flexible and inextensible and that can be approximately considered an ideal rope.

LAB SHEET

In physics, tension is the force exerted by a rope, string, cable, or similar object on one or more objects. Anything pulled, hung, supported, or swung from a rope, string, cable, etc. is subject to the force of tension. But *what is* the tension of a rope? Let's experience the characteristics of this force.

Tools and materials: mass holders with hook and masses (or block with hook), thin wires, dynamometers of different sensitivity and capacity, elastic bands.

Attach one end of the wire to the hook of the mass holder, hold the other end and keep the wire vertical



A) Don't lift the block, and/or the mass-holder from the table, and:

- Show the direction of the tension exerted on the block by the rope.
- Draw the force diagram on the mass holder
- Can you vary the magnitude of the tension? What happens if you lower your hand?
- Can you push the mass holder downwards?
- Can you move the weight holder / block horizontally if you keep the wire vertical?
- How can you move the block horizontally?
- What can you conclude about the direction of the tension?

B) Repeat experiment A) using a rubber band. Highlight the differences.

C) Lift the mass holder and keep it suspended and still

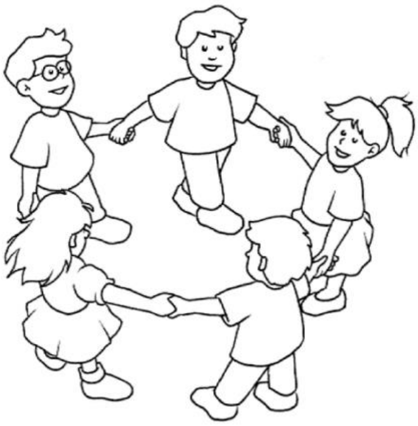
- What is the direction of the force (tension) exerted on the block?
- Draw the force diagram on the mass holder
- Draw the force diagram on the wire
- Measure the magnitude of this force with a dynamometer of appropriate capacity

D) Repeat experiment C) using a rubber band. Highlight the differences.

E) Now attach two ropes to the mass holder hook, lift the mass holder and keep it suspended.

- What is the direction of the forces (tensions) exerted by each of the two wires on the block?
- Draw the force diagram on the mass-holder/block in this case
- What can you conclude on the direction and magnitude of the tension on each of the two wires?
- Check your previous statement by placing two dynamometers in the middle of the two sections of the wire.
- Now, asking for help, or using both hands, keep the block raised with the two ropes forming an angle with the vertical. Has the tension of each rope increased or decreased compared to the previous case? Explain
- Use the two dynamometers to check your answer. Place both ropes in such a way that they form an angle of 60 °with the vertical. What do the two dynamometers indicate? Explain
- Imagine cutting the wire that holds the block. Tension is the force that holds the two ends of the wire together.

It is a bit like a ring-around-the-rosey:



Why can a rope break when prompted by a too intense force?

- Check your answers to the questions I and II.

FIX CONCEPTS AND REFLECTIONS

- Indicate plausible values for the order of magnitude of the tension of the indicated ropes to situations shown in the figure. Can the indicated ropes be considered *ideal*?

(0,1 N)

(10 N)

(1000-10000 N)

(100 N)

(1000-10000 N)

- We can safely hang ourselves on a clothesline when it is vertical, but we break the rope if we try to make it support our weight when it is stretched horizontally, why?

Experiment 2

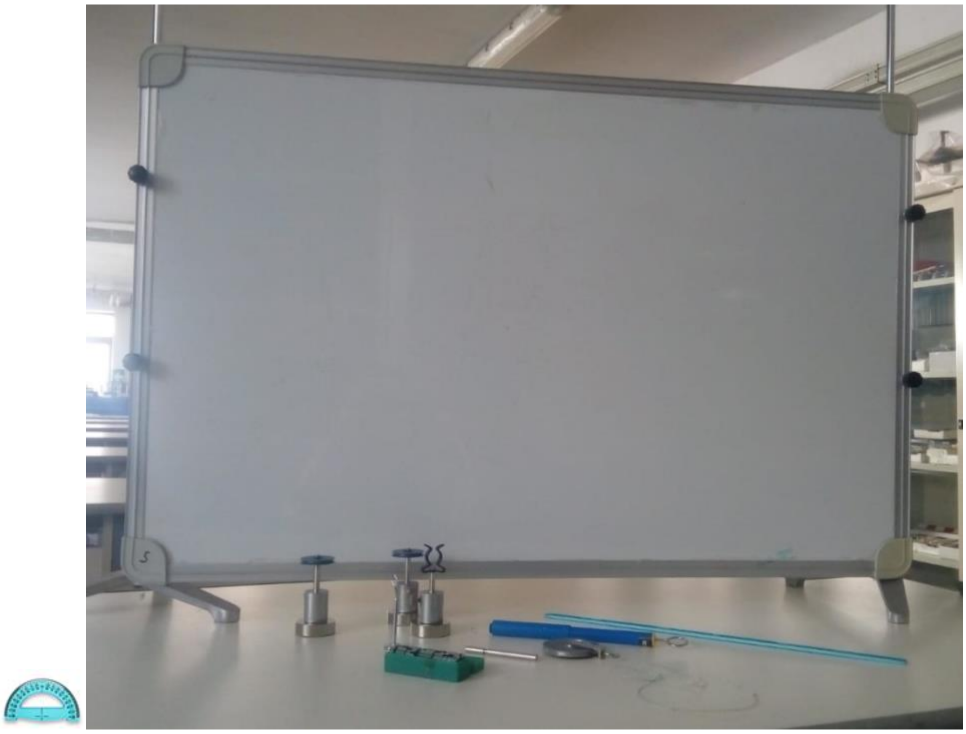
TITLE: THE FIXED PULLEY

FOR THE TEACHER

The experiment and the questions are intended to clarify what fixed pulleys are; that a single fixed pulley changes only the direction of the force (you pull down and the weight goes up.); and that a pulley can create an advantage to the user simply by changing the direction of the effort force even if it doesn't change the intensity of the force.

LAB SHEET

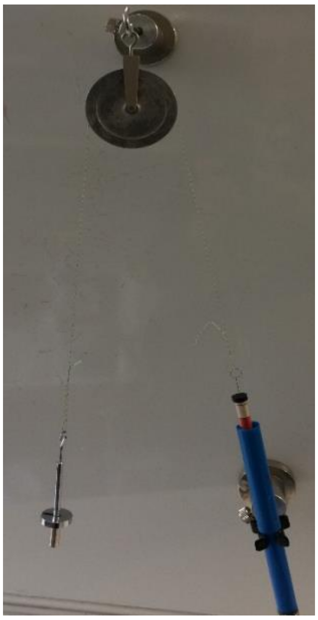
Equipment



The equipment used for the experiment: magnetic board, fixed pulley, magnetic supports, cord, dynamometer clamp, precision dynamometer (range 1,20 N sensitivity 0,01N) or dynamometer resettable according to the setup, full scale suitable for the weight of the masses, ruler (50 cm, 1mm), thin ropes, protractor, 20 g mass series.

Procedure:

- Look at the pulley and describe it. Locate the pulley bracket and throat.
- Mount the device as shown in the figure and measures the force indicated by the dynamometer for different masses of the load.
- Remember to reset the dynamometer every time



Repeat the measurements by varying the inclination of the rope where the dynamometer is attached. Use the protractor to measure the angle that the dynamometer forms with the vertical.

- Fill in the table below:

Table 1

M (g) Mass of the load	S_L (cm) Load displacement	S_D (cm) Dynamometer displacement

Raise the load and measure how much the load is raised and how low the dynamometer is.

- Fill in the table below:

Table 2

M (g) Mass of the load	P (N) Load weight	F (N) Force measured by the dynamometer	Angle that the dynamometer forms with the vertical

- Check that within the experimental errors the force F measured by the dynamometer is equal to the weight of the load. Check that this is true even if you change the direction of the cord in the branch where it is applied F. (Table 1)

- Verify that the mechanical advantage of a fixed pulley is 1 (Mechanical advantage =Load/Input Force (F))
- A student asserts that a fixed pulley is a first type lever in which the arm of power is equal to that of resistance. Do you agree? Explain your answer
- What is the tension of the rope on the side where the dynamometer is applied?
- Indicate magnitude and direction of the rope tension.
- What is the tension of the rope on the side where the load is applied?
- Indicate magnitude and direction of the rope tension.
- Draw the load free-body diagram
- Check, within the experimental errors, that the displacement of the dynamometer is equal to the displacement of the load. (Table 2) Check that this is true even if you change the direction of the cord in the branch where it is applied F.
- Check, within the experimental errors that the work done by the force F is equal to the work of the load weight force
- Check your answers to the questions before the experiments V an VI. Which are your conclusions?

Experiment 3

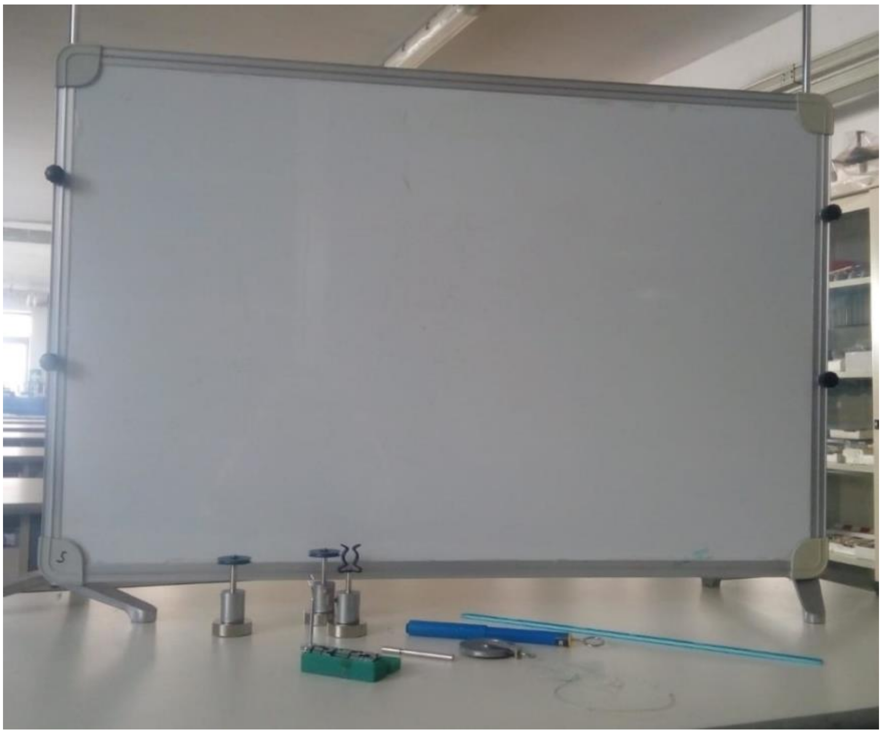
TITLE: THE MOBILE PULLEY

FOR THE TEACHER

In this experiment the students will understand the working of a mobile pulley, that even the pulley has a weight and we need to take it into account, what is an ideal pulley, that by mobile pulleys we can reduce the effort, that there are similarities between levers and pulleys and if we use combination of fixed and mobile pulleys we can have a mechanical advantage.

LAB SHEET

Equipment



The equipment used for the experiment: magnetic board, fixed and mobile pulleys, cord, dynamometer clamp, precision dynamometer (range 1,20 N sensitivity 0,01N) or dynamometer resettable according to the setup, full scale suitable for the weight of the masses, ruler (50 cm, 1mm), thin ropes, 20 g mass series

Procedure:

- Take note of the weight of the mobile pulley ($P_c = m_c g$) and of its error (consider negligible the error on g= 9,81 m/s^2) : Pc =_______±_______.
- Mount the device as shown in the figure below
- Add to the wire attached to the pulley a weight ***P***, that will be our load force, measure *P=m g*
- Measure F on the dynamometer when the system is balanced. F will be our input force to support the load.

- Add to the hook hanging on the mobile pulley some different weights ***P***, then search for the appropriate force **F** to obtain the balance of the system. Measure P=*mg* of each one and measure F on the dynamometer.
- Complete the following table:

Table 1

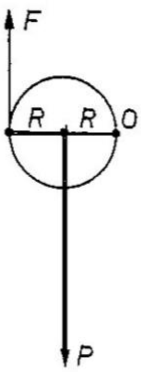
P (N)	ΔP (N)	F (N)	ΔF (N)	$P + P_c$ (N)	$\Delta (P + P_c)$ (N)

Observe and compare the values of F and of $P + P_c$. You can also use a graph by reporting abscissa $P + P_c$ and ordinate F.

- Write the relation between F and $P + P_c$, did you expect this result?

(Within the experimental errors, students should find F = (P + Pc) / 2)

- Now observe the figure below:



Recognize the arms of a lever inside the mobile pulley and complete the following sentences:

The fulcrum (center of rotation) is the point __________;

The lever arm of the load is ________;

The lever arm of the input force is _____.

Now we can analyze the torque balance condition: $F \cdot 2R = (P + P_c) \cdot R$

- Draw the mobile pulley and the load's free-body diagram and discuss the theoretical torque balance condition relationship with the experimental results
- The Mechanical Advantage of a mobile pulley is:
  load force/input force = _____________
- Move the mobile pulley and its load P upwards. Measure how much the the center of the movable pulley is raised and how much you need to lower the dynamometer so that the wire is always tight and the system in balance.
  Check, within the experimental errors, that the displacement of the dynamometer is two times the displacement of the movable pulley. Explains this result
- Has the F value indicated by the dynamometer changed?
- Calculate the work done by the force F, supposed constant during this movement, and the work of the weight force of the mobile pulley and its load. What do you observe?
- Move W down and measure the displacement. How high is P raised? Justify your observation
- Check your answer to the question before the experiments VII . Which is your conclusions?

Experiment 4

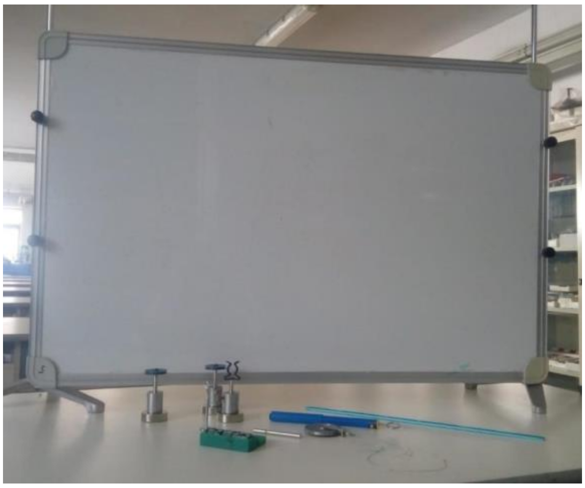
TITLE: MIX OF TWO MOVABLE PULLEYS AND A FIXED ONE

FOR THE TEACHER

The experiment and the questions are intended to clarify and verify that this layout of pulleys creates a greater advantage than the previous one, because it further reduces the intensity of the applied force, but at the expense of a greater displacement. What clearly emerges from this experiment is that the work done by the weight of the load P equals the work of the input force F.

LAB SHEET

Equipment



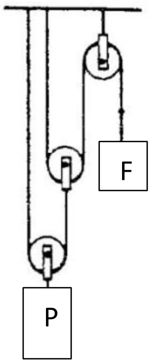


Fig. 1

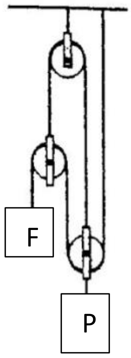


Fig. 2

Equipment used for the experiment:

magnetic board, 3 magnetic brackets, 3 rods with hook, two movable pulleys, a fixed pulley, precision dynamometer (range 1,20 N sensitivity 0,01N) or dynamometer resettable according to the setup, full scale suitable for the weight of the masses, ruler (50 cm, 1mm), thin ropes, 20 g mass series.

Procedure:

- Look at the pulley systems in figure 1 and 2 and describe them.
- Mount the device as shown in the figure 1, apply a load (masses of the equipment) to the movable pulley
- Take note of the weight of the mobile pulley ($P_c = m_c g$) and of its error (consider negligible the error on g= 9,81 m/s^2) : Pc =________±________.
- Measure the force F indicated by the dynamometer when the system is balanced, for different loads, varying the number of the hanging masses. Include the weight of the lowest pulley in the total load weight so that P_{tot} is the weight of the hanging masses and the pulley. F will be our input force to support the total load.

Remember to reset the dynamometer every time.

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Fill in the table below:

Table 1

P_{tot} (N)	ΔP (N)	F (N)	ΔF (N)

- Mount the device as shown in the figure 2, and again apply a load (masses of the equipment) to the movable pulley.
- Repeat the measurements for the systems shown in figure 2 using the same method.

Fill in the Table 2 with new data:

Table 2

P_{tot} (N)	ΔP (N)	F (N)	ΔF (N)

Now, raise the load as indicated in experiment 3, and measure how much the (center of mass of the) load has been lifted up and how much the (center of mass of the) dynamometer has been lowered down.

Fill in the table below for the layout in figure 1:

Table 3

M (g) Mass of the load	S_L (cm) Load displacement	S_D (cm) Dynamometer displacement

Fill in the table below for the layout in figure 2:

Table 4

M (g) Mass of the load	S_L (cm) Load displacement	S_D (cm) Dynamometer displacement

- Check, within the experimental errors, that in both cases the relation between the force F (supposed constant during this movement), measured by the dynamometer and the weight P_{tot} of the load is F= P_{tot} /4. Check that this is true even if you change the direction of the rope in the branch where F is applied.
- Verify that the mechanical advantage of the system is 4 in both cases (Mechanical advantage =Load/input force (F))
- What is the tension of the rope on the side where the dynamometer is applied? Analyze both case 1 and 2.
- Draw the free-body diagram of the load both case 1 and 2.
- Check, within the experimental errors, the relation between the displacement of the dynamometer and the displacement of the load. (Table 3 and 4). Verify that there is a strong connection with the relation between the force F measured by the dynamometer and the weight P of the load. Check that this is true even if you change the direction of the cord in the branch where F is applied.
- Check inside the experimental errors that the work done by the force F is equal to the work done by the load weight force.
- Do you think that the ceiling is holding the weight of the load?
- What is the role of the first pulley on the top of figure 1? [redirect the input force]
- Check your answers to questions V an VI before the experiments. Which are your conclusions?

Experiment 5

TITLE: PULLEYS IN SERIES

FOR THE TEACHER

The experiment and the questions are intended to clarify and verify that the system of pulleys in series can create a great advantage for the user as it changes the intensity of the applied force, but at the expense of a greater displacement.

LAB SHEET

Equipment

Equipment used for the experiment:

magnetic board, magnetic bracket, a rod with hook, two double and triple pulleys in series, cord, precision dynamometer (range 1,20 N sensitivity 0,01N) or dynamometer resettable according to the setup, full scale suitable for the weight of the masses, ruler (50 cm, 1mm), thin ropes, 20 g mass series.

Procedure:

- Look at the pulley system and describe it.
- Mount the device as shown in the figure, apply a load to the pulley system (masses of the equipment).
- Measure the force indicated by the dynamometer for different layouts of the total load, including the mass of the pulley system in the load. (Follow the instructions of experiment 4).
- Remember to reset the dynamometer every time.
- Fill in the table 1A below:

Table 1A

M (g) Mass of the load	P_{tot} (N) Total Load weight	F (N) Force measured by the dynamometer

Now raise the load and measure how much the load has been lifted up and how much the dynamometer has been slowed down.

Fill in the table below:

Table 2A

M (g) Mass of the load	S_L (cm) Load displacement	S_D (cm) Dynamometer displacement

- Check, within the experimental errors, that the relation between the force F (supposed constant) measured by the dynamometer and the weight P_{tot} of the load is F= P_{tot} /4. Check that this is true even if you change the direction of the rope in the branch where F is applied. (Table 1)
- Verify that the mechanical advantage of pulleys in series is 4
- Which is the tension of the rope on the side where the dynamometer is applied? Draw free-body diagram of the load.
- Check, within the experimental errors, the relation between the displacement of the dynamometer and the displacement of the load. (Table 2). Verify that there is a strong connection with the relation between the force F measured by the dynamometer and the weight P of the load. Check that this is true even if you change the direction of the cord in the branch where F is applied.
- Check, within the experimental errors, that the work done by the force F is equal to the work of the load weight force.
- Do you think that the ceiling is holding the weight of the load?
- What is the utility of the first pulley on the top? [redirect the input force]
- Check your answers to questions V an VI before the experiments. Which are your conclusions? [*the input force less by increasing the input displacement; mechanical advantage=number of supporting loops (not strings, because they're not separate strings)*]

- What do you expect the answers to be if instead of having two pulleys in series you have three as in the picture below?

Annex 2 – Infographics

GEAR

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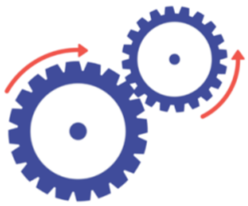
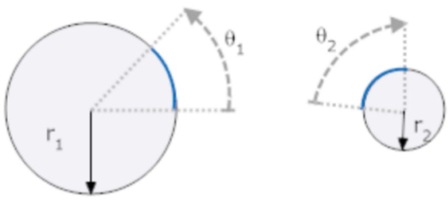
GEAR

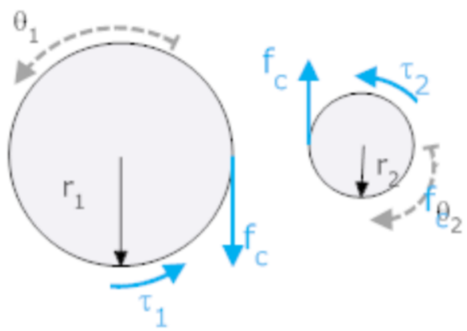
GEARS ARE WHEELS WITH TOOTHED EDGES THAT ROTATE ON AN AXLE OR SHAFT.

Where the gears meet, the teeth must both move in the same direction. This means that the gears rotate in opposite directions.
The forces acting on the teeth are identical for both gears, but their moments are different.

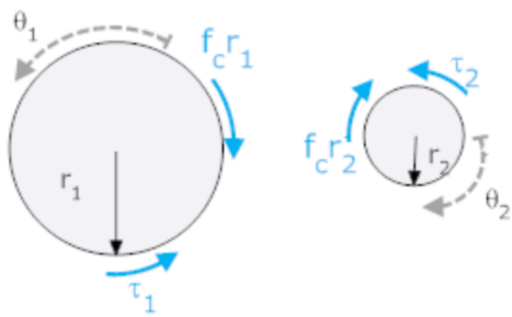




$r_1\theta_1 = r_2\theta_2$ = arc length



Contact force must be equal and opposite across the interface between the two gears, but its direction is arbitrary.



$$\tau_1 = f_c r_1 \quad \text{so } f_c = \frac{\tau_1}{r_1}$$

$$\tau_2 = f_c r_2 \quad \text{so } f_c = \frac{\tau_2}{r_2}$$

$$\frac{\tau_1}{r_1} = \frac{\tau_2}{r_2}$$

$$\tau_1 r_2 = \tau_2 r_1$$

INCLINED PLANE

www.stemap.eu/inclined-plane

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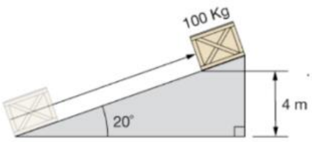
INCLINED PLANE

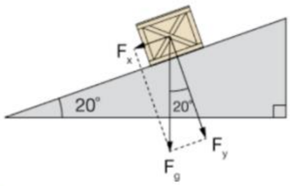
INCLINED PLANE IS MADE OF A FLAT SLOPED SURFACE AND ITS PURPOSE IS TO MOVE SOMETHING FROM A LOWER HEIGHT TO A HIGHER HEIGHT WITH LESS EFFORT.

$$F_g = 100Kg \cdot 9.8 \frac{m}{s^2} = 980\ N$$

$$F_x = F_g sin(20^{\circ}) = 335.18\ N$$

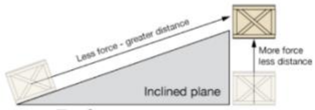
$$F_y = F_g cos(20^{\circ}) = 920.90\ N$$





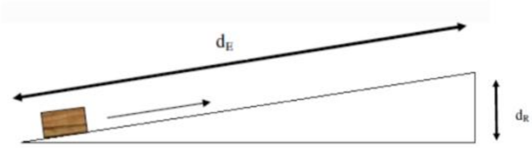
Any type of machine transmits **mechanical energy**, and a measure of its usefulness is the ratio of the output force (Fr) to the input force (Fe). This ratio is the actual mechanical advantage:

AMA = Fr/Fe



$$\begin{aligned} w &= F \cdot d \\ &= 335.28\ N\,(11.695\ m) \\ &= 3921\ J = 3.92\ KJ \end{aligned}$$

$$\begin{aligned} w &= mgh \\ &= F_g\,h \\ &= 980\ N \cdot 4.0\ m \\ &= 3920\ J = 3.92\ KJ \end{aligned}$$

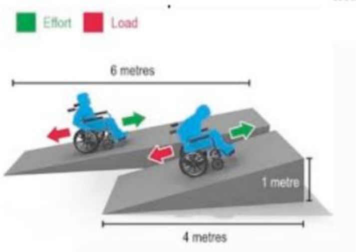


ideal mechanical advantage = $\frac{\text{effort distance}}{\text{resistance distance}} = \frac{\text{length of ramp}}{\text{height of ramp}}$

$$IMA = \frac{d_E}{d_R}$$

actual mechanical advantage = $\frac{\text{resistance force}}{\text{effort force}}$

$$AMA = \frac{F_R}{F_E} = \frac{35\ N}{15\ N} = 2.3$$



Because a certain amount of the input force is needed to overcome friction, and this amount is unknown, it can be difficult to measure actual mechanical advantage. The ideal mechanical advantage, on the other hand, is simply the ratio of the input distance D*i* to the output distance D*o*.

A machine multiplies force. How effective the machine is in that is called efficiency. Efficiency is expressed as a percentage. Efficiency can be determined by the following equation.

$$\text{efficiency} = \frac{\text{actual mechanical advantage}}{\text{ideal mechanical advantage}} \times 100$$

$$\text{efficiency} = \frac{AMA}{IMA} \times 100$$

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LEVER

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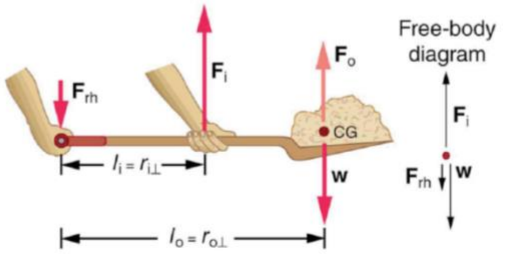
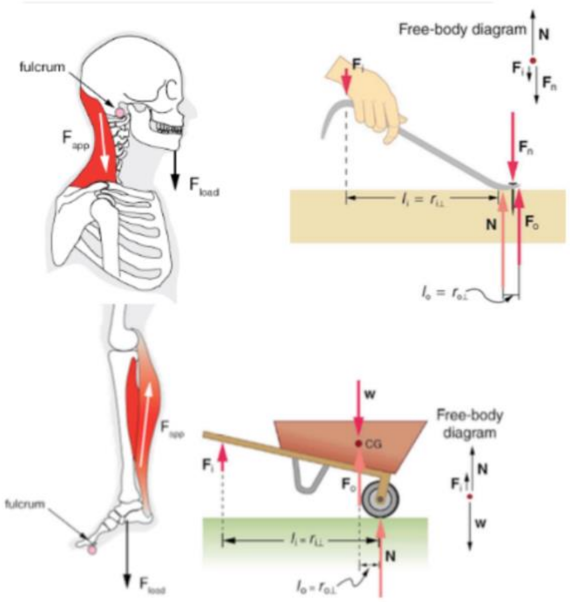
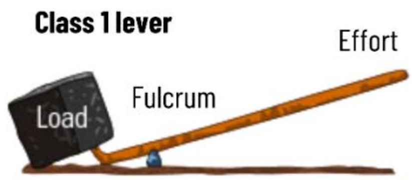
STEMaP LEVER

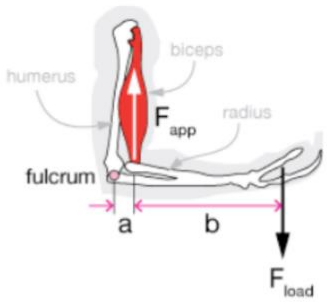
A LEVER ALLOWS US TO GAIN A MECHANICAL ADVANTAGE IN MOVING AN OBJECT OR IN APPLYING A FORCE TO AN OBJECT.

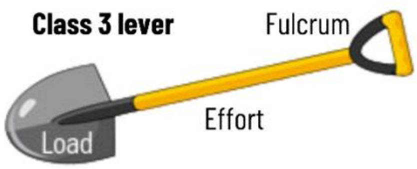


Mechanical advantage = lenght of the fort arm / lenght of resistance arm









PULLEY

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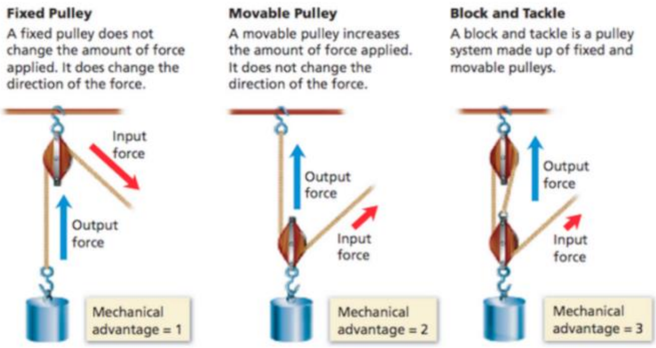
PULLEY

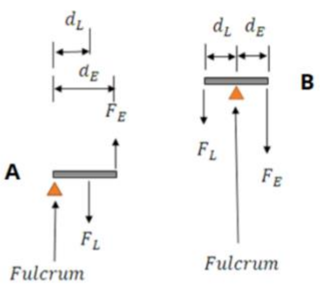
PULLEY SYSTEMS MAKE IT EASIER TO LIFT A LOAD, BECAUSE EACH PART OF THE SYSTEM SUPPORTS PART OF THE LOAD'S WEIGHT.

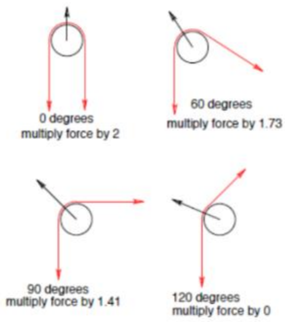


How are levers and pulleys similar and different?

A pulley is similar to a lever in that a pulley can be considered to act exactly the same as an infinite number of levers arranged in a circle about an axis.

A pulley is different to a lever because it is a form where those infinite number of levers "merge" to become a pulley, and a pulley can be used to transmit continuous rotary motion, unlike a single lever, which can only act in an arc.



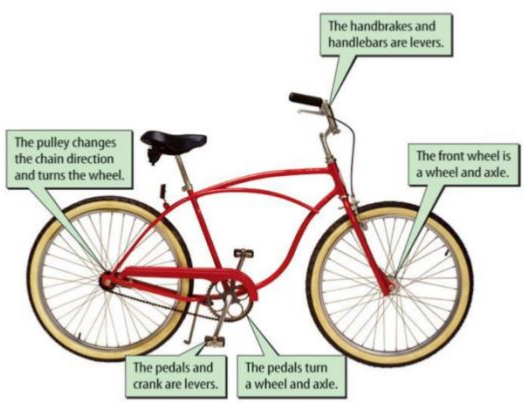


There are three simple machines found on a bicycle: lever, pulley, and wheel-and-axle. Wheel-and-axle is the most obvious. The bike contains wheels and axles in the front and rear wheels. A wheel-and-axle is simply a wheel that rotates on an axle as shown below.

A second machine is the pulley. It is located where the bicycle chain and gears are. The chain is wrapped around the pulley which turns and causes the wheel to turn on its axle

The third machine is the lever. The pedal is a lever. When force is applied to the lever it moves down, and causes the pulley to turn.

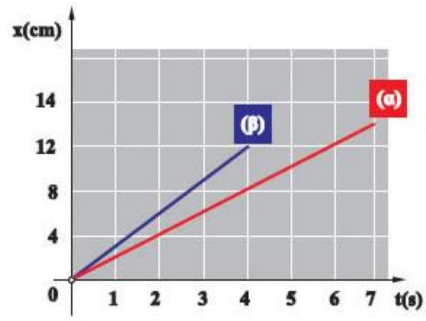
When you ride a bike, energy is transferred from the force of your legs to the lever (pedal). Energy goes from the lever to the pulley (chain and gear), and finally to the wheel and axle, and then to the ground under the wheel, which makes your bike move.



Annex 3 – Complex Machines

www.stemap.eu/complex-machines

MOTOR ENGINES - KINEMATICS



Laboratory exercise: LINEAR MOTION STUDY

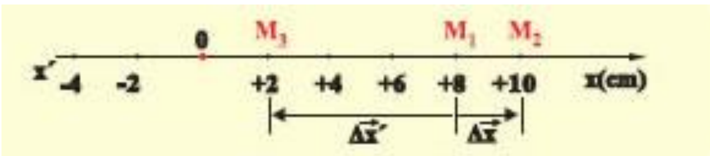
THEORETICAL PART

How could the movement of a racing car be described? How fast does the ball that kicked a footballer move? Answers to such questions gives the **Kinematics** Which describes the movements of the bodies.

The orbit of a moving body is the sum of the successive positions from which the body passes.

If the trajectory is straight, then the movement is characterized as **Inline**, while if it is curved as **Curvilinear**.

BODY DISPLACEMENT ON AXIS: We define as Shift Dx of the body on the straight line the difference x_2 - x_1.



Pict. 1: *Displacement is vector*.

Duration: The difference Δt of the temporal passage of a body from two positions is called **Duration** of its movement between these positions:

$$\Delta t = t_2 - t_1 \quad (1)$$

THE CONCEPT OF SPEED IN INLINE SMOOTH MOTION

Defined as the quotient of the shift to the corresponding time duration.

$$\vec{\upsilon} = \frac{\Delta\vec{x}}{\Delta t} \quad (2)$$

The speed definition equation shows that the AEX offset is:

$$\Delta x = \upsilon\, \Delta t \quad \text{or} \quad x = \upsilon\, t \quad (3)$$

This relationship is called **Animation equation.**

In addition to the algebraic study with the motion equation, the inline smooth movement can be studied and graphically by means of the diagram of the position in relation to the time t.

The slope of the straight at the diagram gives the speed in the straight motion.

Experimental part

INSTRUMENTS, APPARATUS AND MATERIALS:

- Timer

- Tape measure
- Air tube orbit

EXPERIMENTAL PROCEDURE:

A. Linear Smooth motion study

Fig. 2: *Graph x =F (t)*

- Set the air tube orbit in function.
- Next to main part of the air tube you can see a tape so that you know the position of the "train" every time.
- With the help of a timer, determine the times when our train is passing through specific positions.
- Record the values of places and time points in Table 1.

Fig. 4: *Linear Smooth Motion study layout*

Table 1

Position x (cm)	**Time t (s)**	**Change of position Δx (cm)**	**Time Δt (s)**	**Average Speed υ (cm/s)**
x_1=	t_1=			
x_2=	t_2=	$\Delta x_1=x_2-x_1$=	$\Delta t_1=t_2-t_1$=	υ_1=
x_3=	t_3=	$\Delta x_2=x_3-x_2$=	$\Delta t_2=t_3-t_2$=	υ_2=
x_4=	t_4=	$\Delta x_3=x_4-x_3$=	$\Delta t_3=t_4-t_3$=	υ_3=
x_5=	t_5=	$\Delta x_4=x_5-x_4$=	$\Delta t_4=t_5-t_4$=	υ_4=
Average value		$\Delta\overline{\chi}$=	$\Delta\bar{t}$ =	$\Delta\overline{\upsilon}$ =

- Design the shift – time graph. What do you notice about the slope? Speed is fixed or altered;

MOTOR ENGINES – PENDULUM

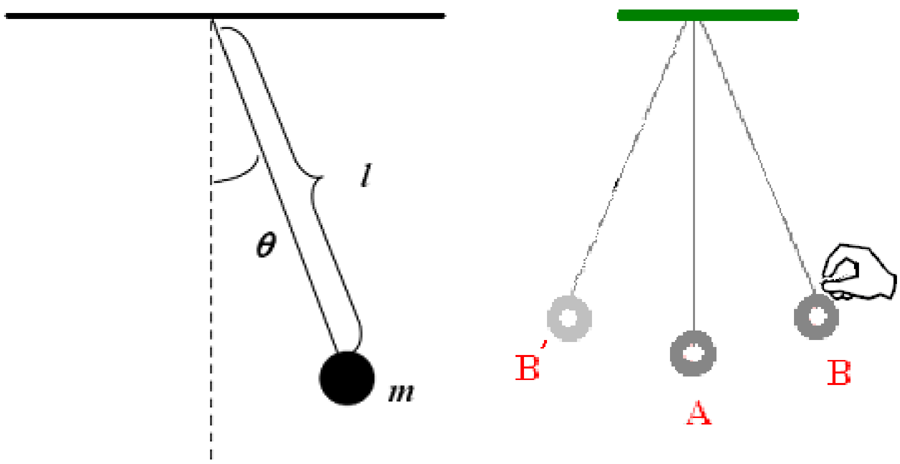
Laboratory exercise: PERIODIC MOVEMENTS-OSCILLATIONS

THEORETICAL PART

Simple pendulum

When a move is repeated at equal intervals it is called periodic. In the event that a periodic movement becomes reciprocated around a position of equilibrium then it is called oscillation.

The simple pendulum consists of a small-sized heavy body, usually a pellet, that hangs with a thin thread from a fixed point and can move freely around it, making oscillations on a vertical plane. If the pellet is removed at a small angle θ (fig. 1a) from its equilibrium position, it is left free and ignored frictions and resistances, then due to its weight and the tension of the yarn will make free oscillation between points B and B΄ that are equal Distance from A (Fig. 1b).



Pict. 1 (a): Simple Pendulum, **b** Simple pendulum oscillation around position A.

The pendulum makes a oscillation, if the pellet moves from the B to the B΄ and back to B. The time of an oscillation is the period T of the pendulum. The distance from the dependency point to the center of the pellet is the length l of the pendulum. Considering that such a pendulum makes oscillations of a very small deflection angle ϑ ($\vartheta < 5^o$), the period T of the pendulum is given by the relationship:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Where: π= 3.14 and g= Acceleration of gravity

Experimental part

INSTRUMENTS, APPARATUS AND MATERIALS:

- Timer

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- Ruler
- Iron Hook
- Iron Base
- Iron rod
- String
- Beads (pellets)
- Magnet

Figure 1 *Experimental Apparatus*

EXPERIMENTAL PROCEDURE:

A. Effect of length in the pendulum period

- Use the ruler and measure the length of the thread at 1 m.
- Remove the pellet from the balance position and measure the time of five oscillations. The time measurement starts from the moment you leave it. You say "zero" and you Count "one", "two" etc. when the pellet goes again from the point where you leave it in the "ten" stop the timer. Repeat two or three times. Change the length of the string reducing it each time by 10 cm and fill the following Table 1

Table 1

	l (m)	*10T (s)*	*T (s)*
1			
2			
3			

B. Effect of mass in the pendulum period

- Keeping the length of the yarn fixed (l =*1 m*) mount 3 different weights.
- For each weight, measure the time of 10 oscillations and fill in Table 2.

Table 2

	m (g)	*10T (s)*	*T (s)*
1			
2			
3			

C. Effect of acceleration of gravity in the pendulum period

- Mount the iron ball into the yarn. Place the magnet directly below the balance position of the pendulum For length l $= 1\ m$ divert it by small angle, measure the time of 10 oscillations and calculate the period T of the pendulum. Repeat this procedure for 3 different string lengths and fill the Table 3.

Table 3

Without Magnet			**With Magnet**		
10 T (s)	*T (s)*	*l (cm)*	*10 T(s)*	*T(s)*	*l (cm)*

MOTOR ENGINES – DYNAMOMETER

Laboratory exercise: ELASTICITY – HOOKE'S LAW OF ELASTICITY

THEORETICAL PART

The various materials can be separated in elastics and plastics. When a certain force acts on a body, the body is deformed. If it takes its original form as soon as the power ceases, we call the body elastic. For example, a steel spring is a resilient body. In contrast, a spring of copper wire or a clay is a plastic body, because it deforms permanently even with the effect of small force. An elastic body will suffer permanent deformation, when the force that distorts it surpasses the body's elasticity limit. It breaks when it crosses its fracture limit.

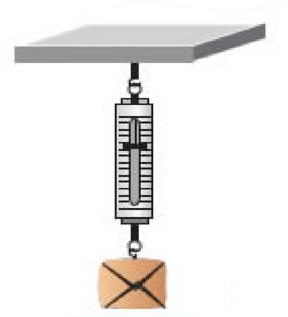
The Hooke's Law or the law of elasticity says that elongation x of a spring in its elasticity regime is proportional to the power of the F that causes it:

$$F=k\cdot x \qquad (1)$$

Where k The constant of the ratio.

We call it the constant k, as "spring constant", while its value characterizes the stifness of the spring and depends on the geometric characteristics of the spring (length, thickness etc.). It has a unit of measurement *1 N/m.*

The law of elastic deformation is based on the measurement of a force with the help of the dynamometer. When we hang a body by a steel spring, the elongation depends on the weight of that body. Twice the weight causes twice as much elongation. So, hanging different bodies of known weights and noting the corresponding deformations we can grade the spring and build a dynamometer!



***Pict. 1**: Dynamometer*

Experimental part

INSTRUMENTS, APPARATUS AND MATERIALS:

- Ruler
- Iron Hook
- Iron Base
- Iron rod
- Masses of 50 gr
- Body of unknown mass
- 2 Springs

***Pict. 2**: Experimental apparatus*

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EXPERIMENTAL PROCEDURE:

- Assemble the experimental device of FIG. 2.
- Hang on the hook on one of the springs. The hook serves as an indicator on the edge of the spring.
- Set the ruler in such a way that the zero mark is on the same line as the hook.
- At the end of the spring, hang a weight. Note the value of the elongation x of the spring.
- Repeat the procedure 4 more times by adding same weight each time, recording the elongation x the spring and the force exerted F=B (weight of pellets). Remember that the weight B of a body is calculated from the relationship: B $=mg$, where g=acceleration of gravity. For your calculations use $g = 10\ m/s^2$.
- Fill in table 1.

Table 1

Spring A		**Spring B**	
B (N)	*x (cm)*	*B (N)*	*x (cm)*

- Follow steps 2 through 6 for the second spring.
- To design the graph $F - x$ for spring A.
- On the same axes, do the graph for the B spring.
- What format do the graphs have? The Law of Hooke; Articulate him.
- Hang from the spring a body of unknown weight and record elongation x of the spring.

x (cm)

- From the graphs you have done can you calculate the weight of the unknown body?

THERMAL MACHINES – THERMAL EXPANSION

Laboratory exercise: THERMAL EXPANSION - BOILING

A. Thermal expansion

THEORETICAL PART

Almost all materials solids, liquids and gases, when their temperature increases (heated), expands, i.e. their volume increases, while when their temperature is reduced (cooled), they contract. This phenomenon is called **Thermal expansion** and the opposite of the phenomenon, **Contraction**. However, all bodies do not expand or contract in the same way. The lid, which is usually made of iron or aluminum, is more contracted than the glass vase so it stocks in the spout of the jar when it is placed in the refrigerator where it is cooled. Of all the bodies the solids expand less, the fluids more and the end gases expand more than all the physical bodies.

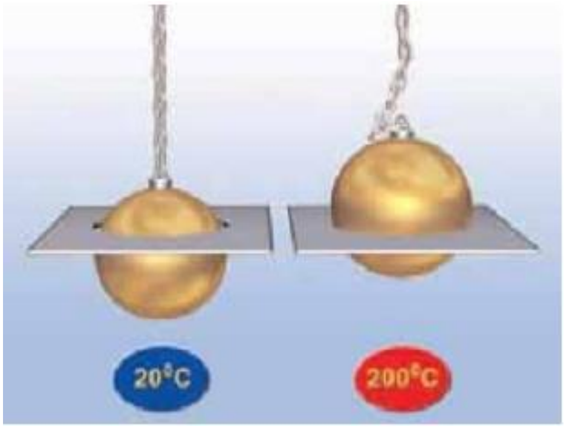

Fig. 1 *Cubic Thermal expansion*

Experimental part

INSTRUMENTS, APPARATUS AND MATERIALS:

- Linear expansion Device
- Thermal expansion Device by volume
- Stove-tripod-mesh
- Water
- Volumetric flask with long neck
- Conical flask
- Balloon
- Candle
- Glass Basin

EXPERIMENTAL PROCEDURE:

- In the volume expansion device, try to pass the ball through the ring. After heating the ball with the stove (**Do not touch the flame in the metal**), try to pass it through the ring. Write down your comments.
- Fill the volumetric flask **Until** I marked it with water. If there is no mark, note the water level with a marker. Place it on the grid and turn on the stove.
- Let it pass for a few minutes. What happens to the water level? Write down your comments.
- Place a balloon in the conical flask. Fill the glass basin with hot water (**There is a kettle**) and place the conical flask inside. What happens to the balloon after a while?

B. Boiling

THEORETICAL PART

Boiling is the fast degassing by producing steam bubbles throughout the mass of the liquid. It starts at a certain temperature, temperature or boiling point, which is typical for each liquid. Thus, for water the boiling temperature is 100°C At atmospheric pressure 1 Atm.

The boiling temperature is a characteristic size of each body. But it depends on the atmospheric pressure exerted on the liquid. In general, increased pressure increases the boiling point, while the opposite occurs when the pressure decreases.

Experimental part

INSTRUMENTS, APPARATUS AND MATERIALS

- Spherical flask 250 ml
- Stove-tripod-mesh
- Thermometer
- Wooden Clothespin
- Water
- Salt

EXPERIMENTAL PROCEDURE:

- In the spherical flask put 100 Ml Water. Fastened the thermometer in the bottle in such a way that the tip of the mercury touches the surface of the water. Position the flask on the grid.
- Note the initial water temperature on Table 1. Light the stove by adjusting the flame low (mild heating). Each 30 s (0.5 min) Indicate the thermometer in Table 1.
- When the water boils what do you observe?
- Let the water boil two more minutes and note its temperature in table 1. Then turn off the stove.

Time t (min)	0	0,5	1	1,5	2	2,5	3	3,5	4
Temperature Θ°C									

Time t (min)	4,5	5	5.5	6	6,5	7	7,5	8	8,5
Temperature Θ°C									

Time t (min)	9	9,5	10	10,5	11	11,5	12	12,5	13
Temperature Θ°C									

HYDRAULIC MACHINES – HYROSTATIC PRESSURE

Laboratory exercise: LAW OF HYDROSTATIC PRESSURE

THEORETICAL PART

When a power *F* It acts on a surface A then the ratio:

$$P = \frac{F}{A}$$

it is called pressure on the surface A. Pressure's unit (SI) is *1 N/m²* and is called Pascal (*1pascal = 1Pa =1 N/m²*). Other pressure units are *1 Bar = 10⁵ Pa = 1 atm.*

The pressure due to the weight of a liquid is called **Hydrostatic.** The hydrostatic pressure P at a certain point in the liquid (if you ignore the atmospheric) is proportional to: the depth from the surface of the liquid h, the liquid density p and the acceleration of gravity g. The above conclusions are expressed in the language of mathematics by the relationship:

$$P=p \cdot g \cdot h$$

(Law of Hydrostatic pressure)

Where: *p* Hydrostatic pressure in *N/m²*, p the density of liquid in *Kg/m*, *g* the acceleration of gravity in *m/s²* and *h* the depth from the surface of the liquid to *m*. It is worth noting that hydrostatic pressure, depends **Not** on the shape of the container or the volume of the liquid. We feel the same pressure when we take a dip and our head is sunk by one meter either in a small seawater pool or in the middle of the sea.

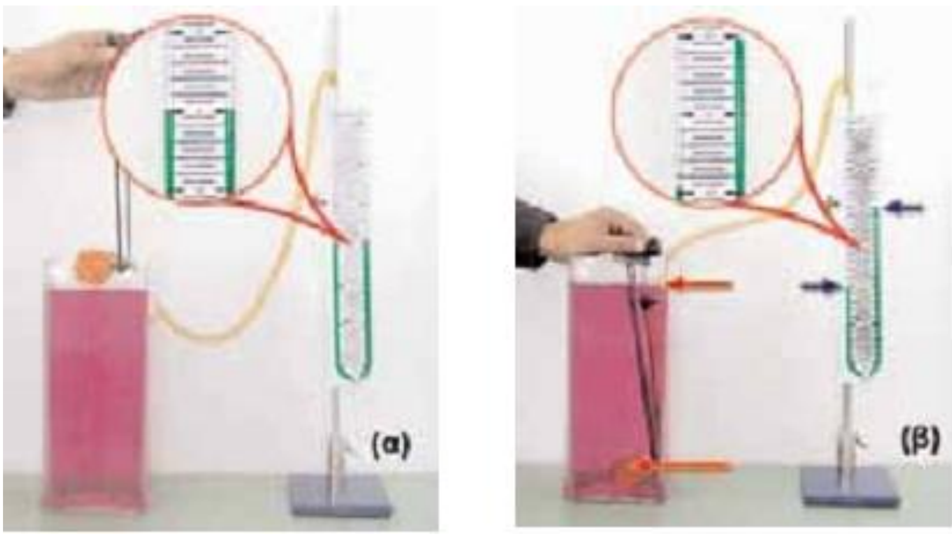

Fig. 1: Measurement of Hydrostatic pressure
(a) the membrane is located outside the liquid (b) The membrane is in the liquid

Experimental part

INSTRUMENTS, APPARATUS AND MATERIALS:

- Manometric capsule with Manometer
- Volumetric Cylinder
- Ruler
- Water
- Concentrate Saline solution

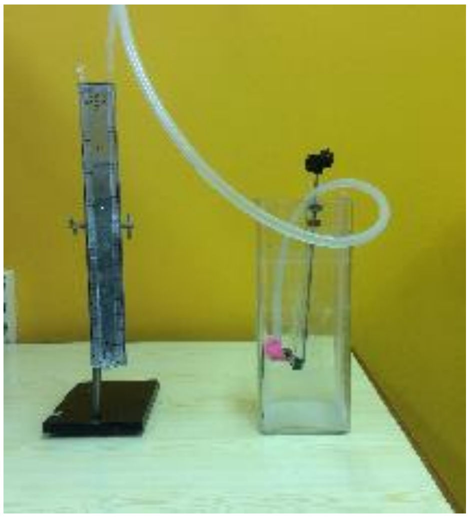

Fig. 2: *Experimental apparatus*

EXPERIMENTAL PROCEDURE:

- Fill the glass basin with water until the ¾. Plunge the Manometric capsule into the water and adjust the height of the device so that the center of the membrane of the manometric capsule is 2 cm under the surface of the water.
- Observe the indication of gauge and fill it in Table 1.
- Continue, repeating procedures 5 and 6 for depths 4 cm, 6 cm, 8 cm, 10 cm etc. Fill in Table 1. What do you notice from these measures? How does hydrostatic pressure change in relation to the depth from the surface of the liquid?
- Fill with a saline solution the plastic basin. Plunged into the saltwater the manometric capsule in 8 cm depth. Observe the indication of gauge. Fill in the respective table 2 field Comparing the values of hydrostatic pressure in water and saltwater, for the same depth. What do you see?

Table 1

Depth *h (cm)*	**2**	**4**	**6**	**8**	**10**
Pressure *P (cm H_2O)*					
Depth *h (cm)*	**12**	**14**	**16**	**18**	**20**
Pressure *P (cm H_2O)*					

Table 2

1	**2**	**3**
Liquid	**Depth h (cm)**	**Pressure p (cmH_2O)**
Water	**8**	
Saltwater	**8**	

- Fill the communicating containers with water. What do you notice? Give an explanation.

HYDRAULIC MACHINES – BOUYANCY

Laboratory exercise: BUOYANCY – ARCHIMEDES' LAW

THEORETICAL PART

Have you ever wondered what forces keeps your body on the surface of the sea when you swim? Which force keeps ships on the surface of the sea, lake or rivers when they travel?

It's the same force that prevents you from sinking a balloon into the water. Each liquid exerts strength on the bodies that sink into it. This power is called **Buoyancy**.

It is easier to lift a stone when it is immersed in the water than when it is outside. You form the impression that the weight of the stone decreases when you immerse it in the water. If you hang it from a dynamometer, the indication of the dynamometer when the stone is in the water is less than the indication when the stone is in the air (Fig. 1). The weight of the stone, i.e. the gravitational force that the earth exerts on the stone, is the same either the stone is in the water or it is in the air.

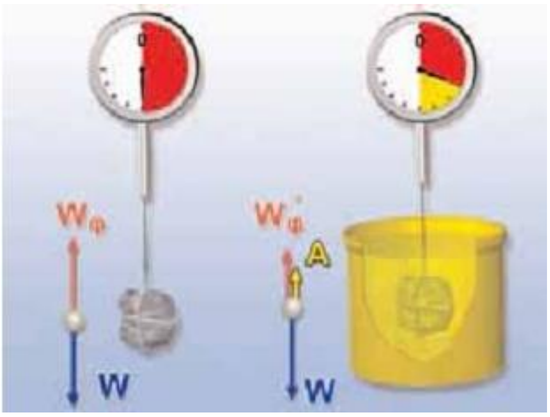

Fig. 1: The buoyancy has a vertical direction and is once upward.

Why does the dynamometer show a smaller indication when the stone is hung in the water? The water exerts on the stone a force that we called buoyancy: A. The indication of dynamometer, W_{ϕ}, is equal to the measure of force the dynamometer exerts on the stone. The stone is balanced. So, when it is in the air, it applies: $W\phi=W$,

While immersed in water: $W'_{\phi}+A=W$, i.e $W'_{\phi}=W-A$, so $A=W - W\phi'$

- Buoyancy does not depend on the shape and weight of the body being immersed.
- If a body is Entire Immersed in the liquid, buoyancy is independent of the depth at which it is located.
- The liquid with the highest density exerts greater buoyancy.
  - Buoyancy increases when the volume of fluid that is displaced by the body is increased, which we plunge into it.

Archimedes gathered all the above observations and formulated a proposal known as **Archimedes ' principle**: **Fluids exert Force in every body that sinks into them. This force is called buoyancy, it is perpendicular, and its value equals the weight of the fluid being displaced by the body.**

$$A = W_{displaced\ liquid}$$

$$A=\rho_{liquid}\cdot g\cdot V_{displaced\ liquid} \quad \text{(Archimedes Law)}$$

Where A is the Buoyancy exerted on a body immersed in liquid with density ρ and $V_{displaced}$ the volume of liquid being displaced.

Experimental part

INSTRUMENTS, APPARATUS AND MATERIALS:

- Dynamometer
- Calibrated Beaker
- Teflon Roller
- Water

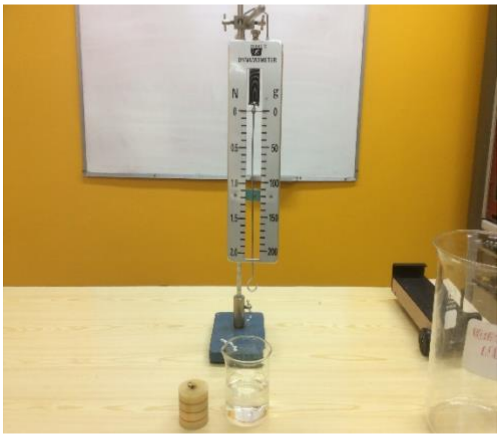

Fig. 4: *Experimental apparatus*

EXPERIMENTAL PROCEDURE:

- We hang from the 2 N dynamometer The cylinder, let it balance and denote the indication of the dynamometer which equals the weight of the roller. So:

$$F_{dyn(air)} = W_{cylinder} = \ldots\ldots N$$

- Fill the beaker up to the Mark 200 ml with water. We sink the cylinder **Until the second mark** (Lowering the dynamometer) and note the indication.

$$F'_{dyn(liquid)} = \ldots\ldots N$$

- Compare the two dynamometer indications. Can you explain the difference you observe? To what force can we attribute the difference between the indications of the dynamometer?
- In step 2, we fill the beaker until the 200 ml and we sunk the cylinder until the second mark. The water level on the beaker went up. Note the volume of water when we sank the cylinder until the second mark. This volume is the *Vdisplaced liquid*.

$$V_{displaced\ liquid} = \ldots\ldots ml$$

- Considering that the water density is $\rho_{Liquid} = 1\ gr/cm^3$ and the $g = 10\ m/s^2$ Calculate from the relationship (2) buoyancy A Applied to the cylinder. Compare this value to the one that you calculated in step 2. What do you notice?
- Why do we float more easily to the sea than to a lake or pool (with "sweet" water)? You can answer the above question if you know that saltwater (seawater) has a higher density than pure water (lake water).

Annex 4 – Mathematical Machines

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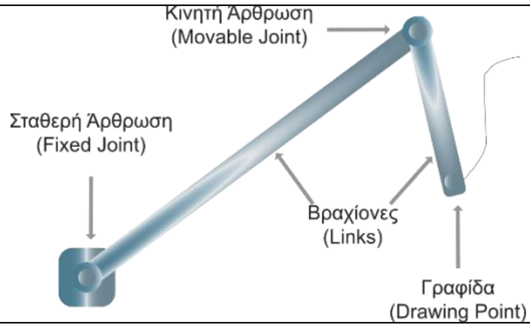
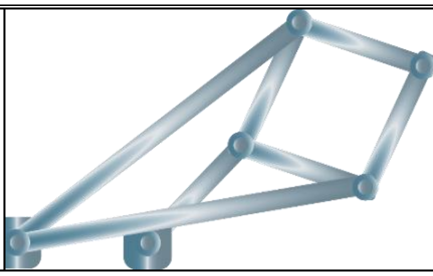
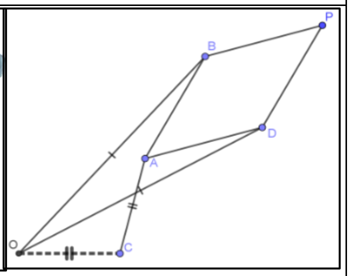
GEOMETRY OF PEAUCELLIER LINKAGE

WORKSHEET	GEOMETRY OF PEAUCELLIER LINKAGE
LINKAGES' DEFINITION	Linkages are mechanisms that used as parts of machines for specific purposes like converting motion. More specific, a form of motion is applied to a linkage - it is considered "driver" or "master" or "input" - and a desired or usable motion is produced that called "follower" or "output" or "slave".
LINKAGES' DESCRIPTION	 A linkage is a collection of links. Links are connected either to each other or to fixed points by joints. Each joint connects two or more links.
ACTIVITY No1	In the above figure you can see a linkage. 1. Describe the motion of the links …………………………………………………………… …………………………………………………………………………………………………… 2. Describe the motion of the drawing point ……………………………………………. ……………………………………………………………………………………………………
PEAUCELLIER LINKAGE	   The first figure shows a replica of Peaucellier's Linkage, the second is its schematic representation and the third one is its geometric representation. How many links, joints and fixed joints are in the linkage? …………………………………………………………………………………………………… Two large-sized OA and OB arms, of equal length, rotate at the same fixed point O while their free ends B and D are attached to the opposite vertices of a ABPD modular linkage composed of four equal sized links, with movable joints. Next, the part of the device described so far is connected by the joint A of the modular linkage with a fixed point C via an additional AC link, the length of which is just as the distance OC. Suppose that a mechanism attached to joint A, could produce movement to it. Try to figure out the motion of the links of the linkage. …………………………………………………………………………………………………… …………………………………………………………………………………………………… ……………………………………………………………………………………………………

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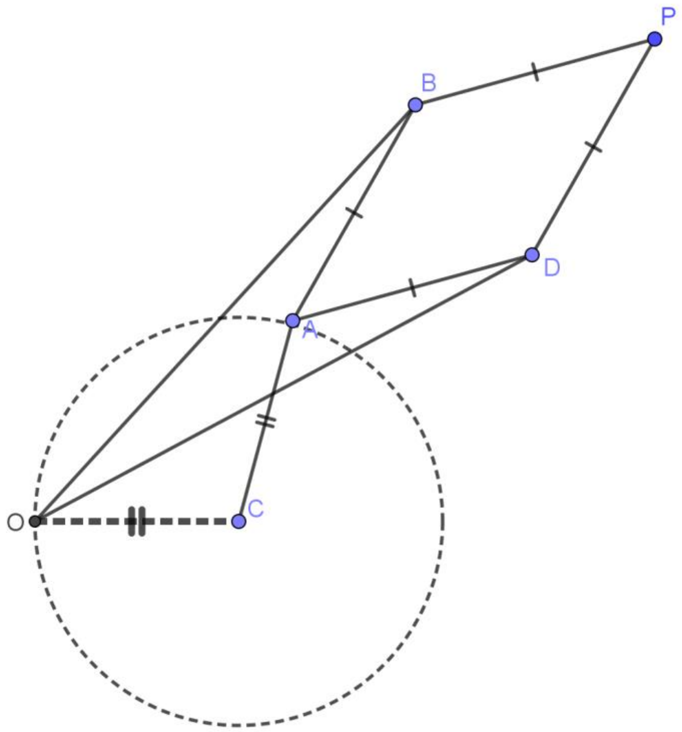
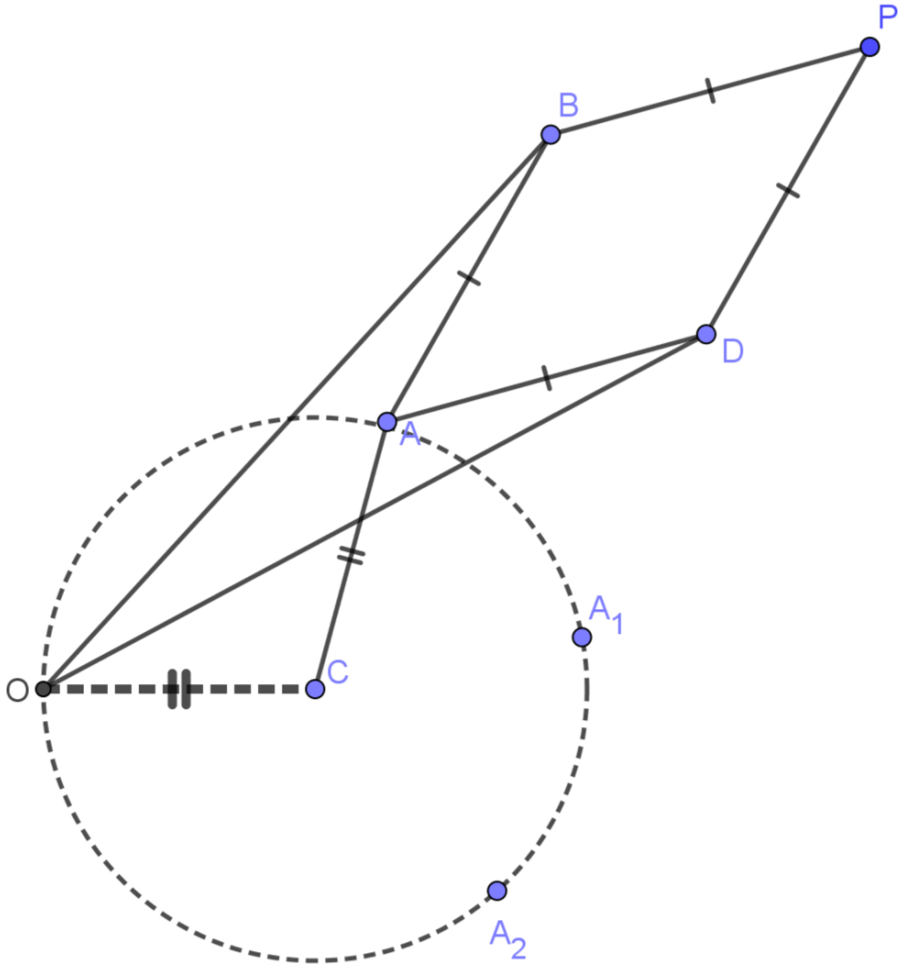
PEAUCELLIER'S LINKAGE GEOMETRIC REPRESENTATION	 This figure shows Peaucellier's Linkage geometric representation. The joint on point A performs circular motion with its center on fixed point C and radius CA. Meanwhile point O is a fixed point positioned on the same circle. Describe the motion of points B and D. ……… ……… ……… Describe all geometric shapes of the figure and their properties. You can draw any line that you think will be convenient. ……… ……… ……… ……… ……… ……… ……… ……… ……… ……… ……… ……… ………

<table>
<tr>
<td>LOCATE POSSIBLE POSITIONS OF POINT P</td>
<td>
Suppose that A_1 is another position of point A. Bearing in mind previous questions design the new position of the mechanism and locate point P. Describe the procedure you followed step by step. Repeat for point A_2.
………..
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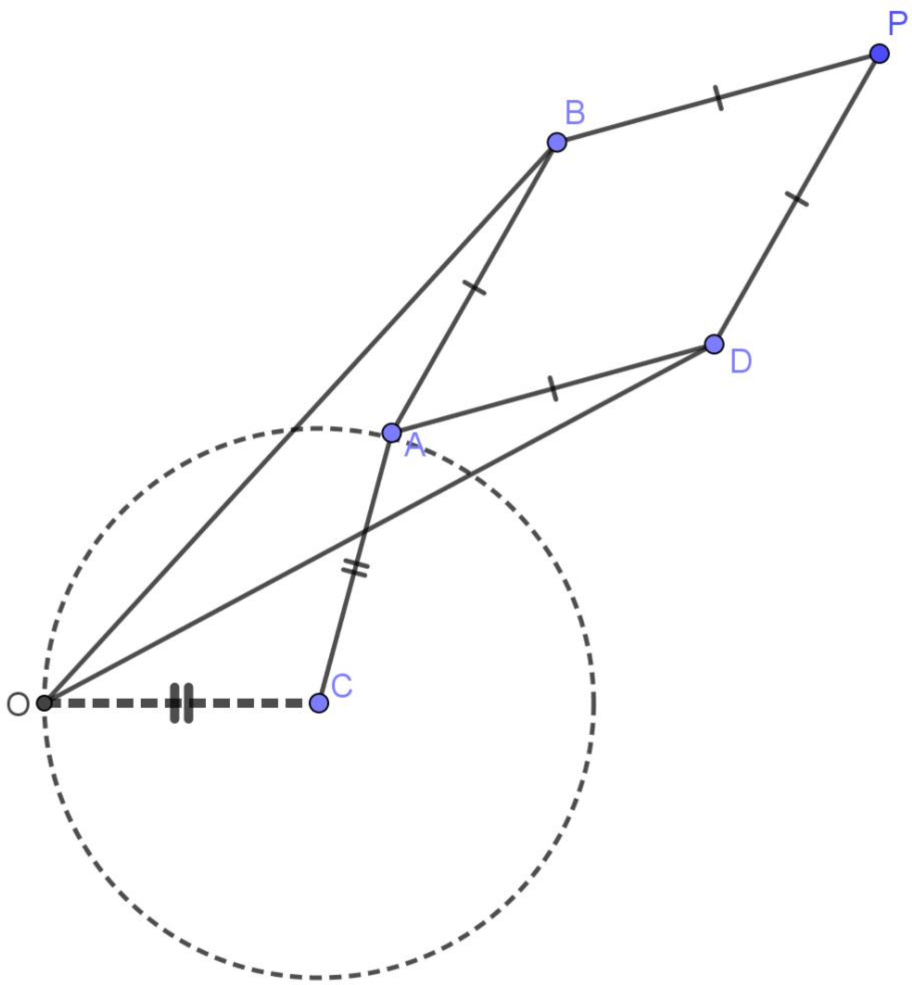
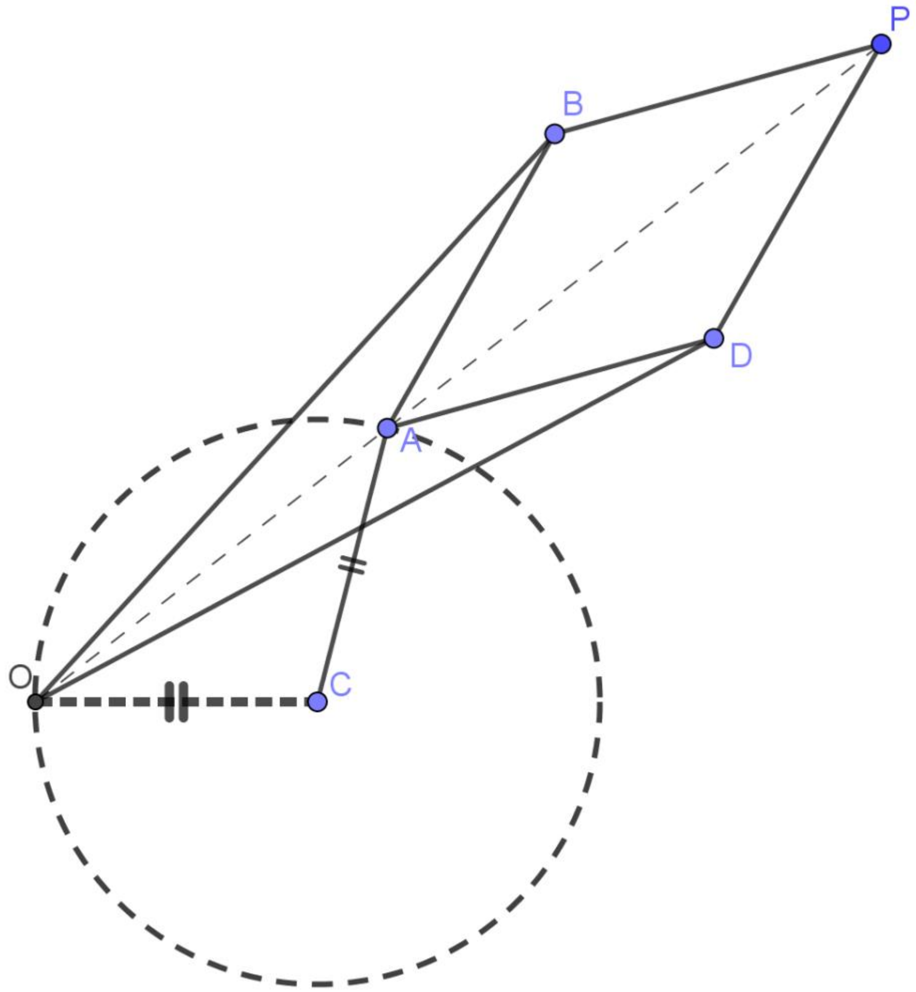
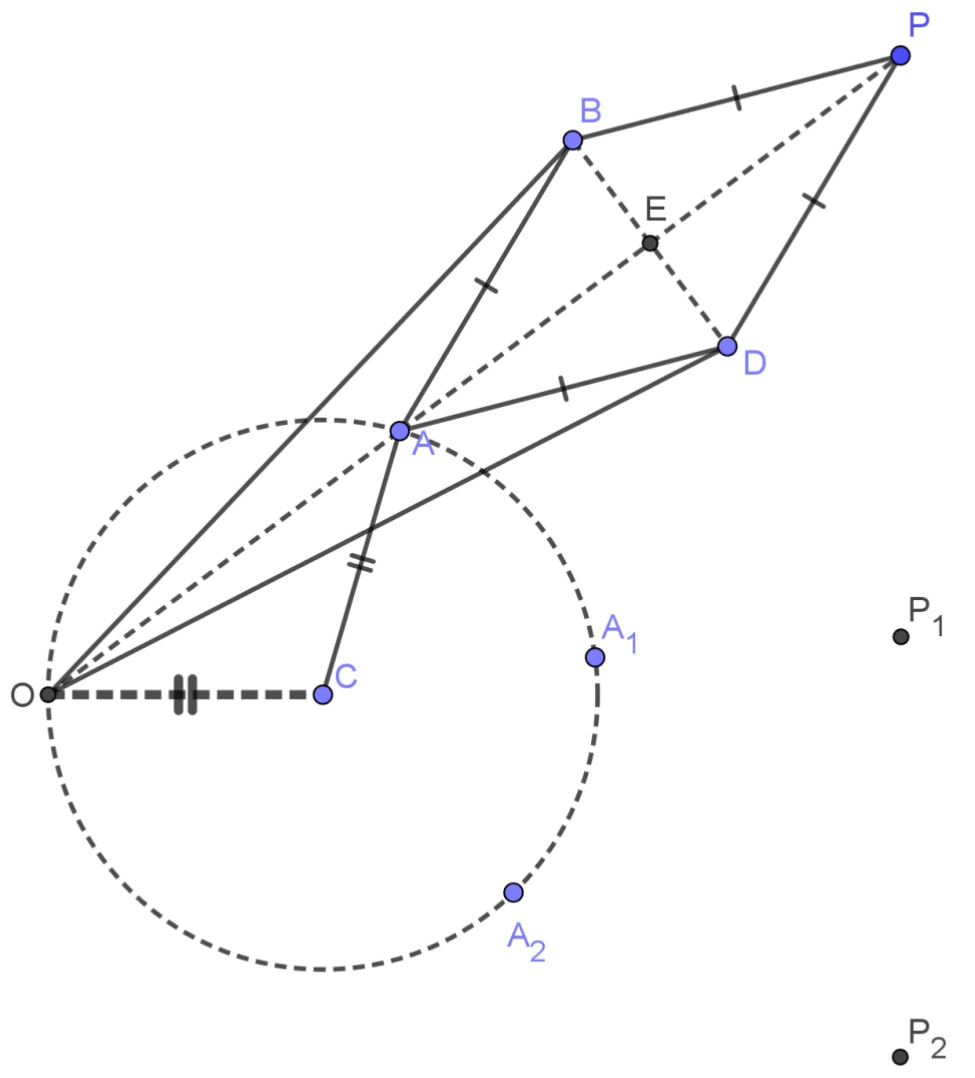
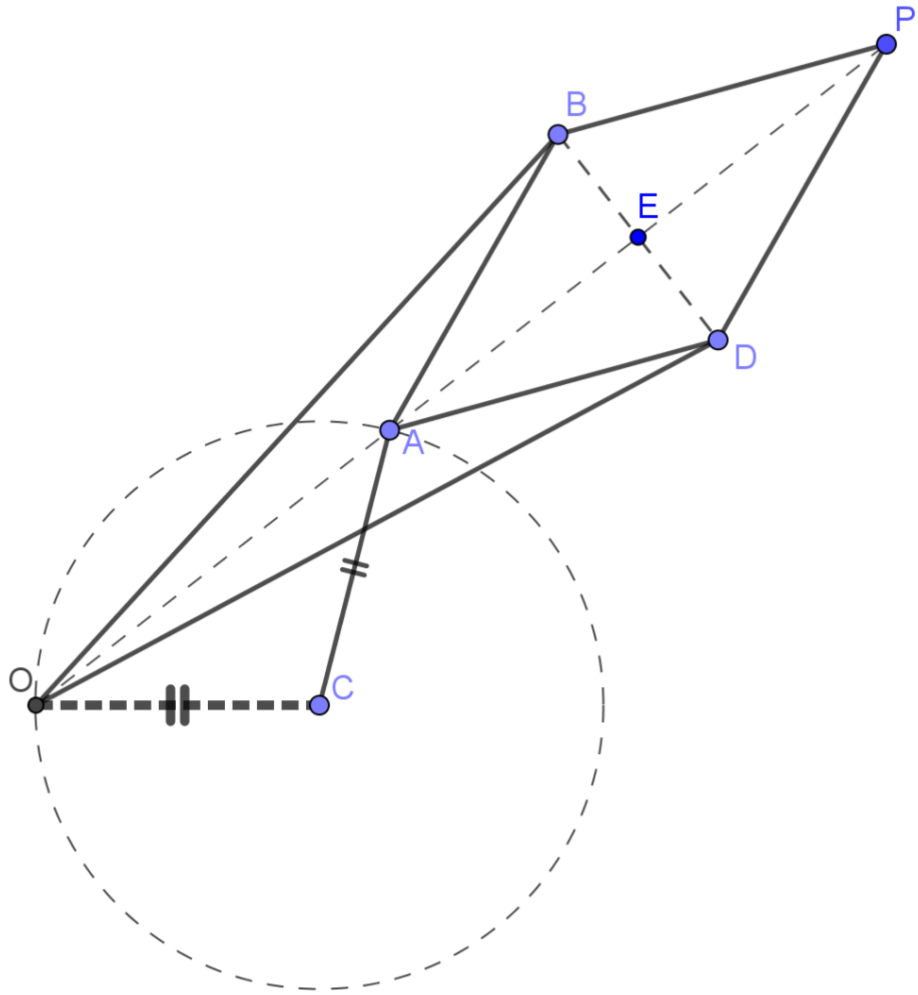
</table>

POINT'S P POSSIBLE POSITIONS	Suppose that there is a pen attached at point P position while point A moves along the circle. Can you guess what kind of drawing will be produced? ……….. ………..
FINDING POINTS MAINTAINING THE SAME RELATIVE POSITION	Study carefully the figure with the possible positions of point P. Try to find three or more points that they maintain constant the relative positions between them. Perform all possible controls. ………..
PROVING	Connect with straight line segments the points O, A and P (if you haven't done so yet). Prove that they are collinear no matter the position of point A.  …… …… …… …… …… ……

CALCULATIONS	Draw the line segment BD (unless you haven't done so yet) in the following figure. Let E be the point of intersection of AP and BD line segments. Calculate the length of line segment OAP. (Tip. An easy way to calculate right triangles' sides lengths is the use of Pythagorean Theorem)  .... (×12)

DETERMINATION OF FIXED SIZE'S SEGMENT	Considering that P_1 and P_2 are possible positions of point P (found during previous activities) determine a geometric shape that has a relationship with the line connecting points P, P_1, P_2. (Tip: Connect all the possible positions of point P while point A is moving along the circle). ……  Apart from the segments PB, PD is there any other points or lines which have fixed distance from point P? Please justify your opinion. …… ……
IDENTIFICATION OF THE GEOMETRIC SHAPE WITH THE FIXED DISTANCE FROM POINT P	Locate the geometric shape that has fixed distance from point P. You can draw any line that will assist you. (Tip: Connect all the possible positions of point P while point A is moving along the circle) …… …… ……

PROVING	Draw any useful line, according to your opinion, in order to prove your assertion. (Tip1: Right triangles are very useful when comes to calculations not only because it is easier to prove the similarity but you can apply Pythagoras theorem as well. Tip2: Modify appropriately the mathematical relationship of OP line segment)  ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ………………………………………………………………………………………………………

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REALITY	Place a sheet of paper under the pen in model of the Peaucellier's Linkage. Locate the position of point A (of the geometric representation) on the model and slide it so it moves along a (fantastic) circle. Now find out the shape of the line that the pen draws. ……… ……… ……… ……… ……… ………

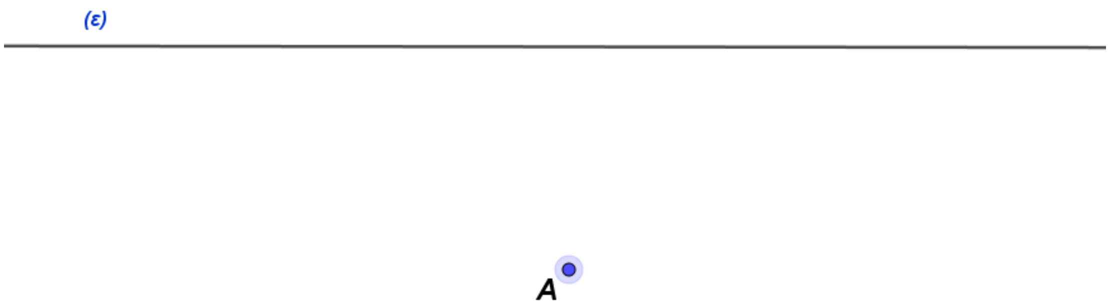
Thank You for your attention

FRANS VAN SCHOOTEN'S MACHINE

WORKSHEET

WARMING-UP PHASE

Find some points that have the same distance from the point A and the straight-line ε.
Can you assume where all these points with this property are situated?



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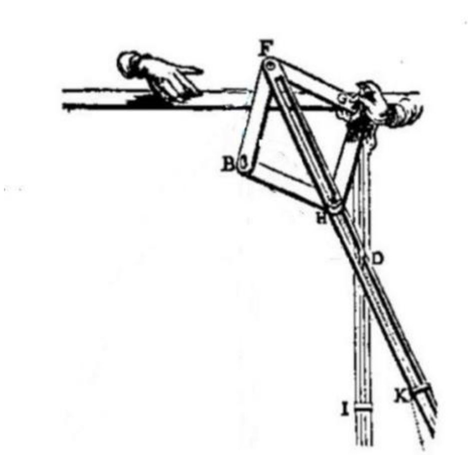
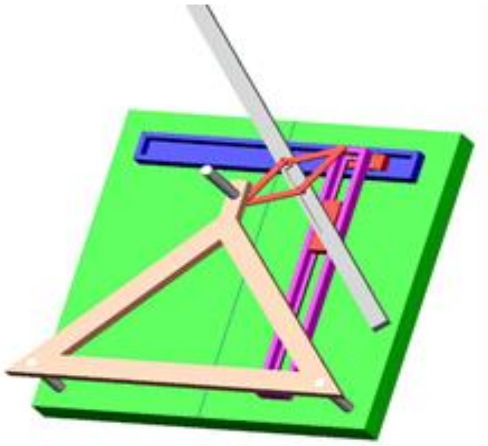
Phase A'

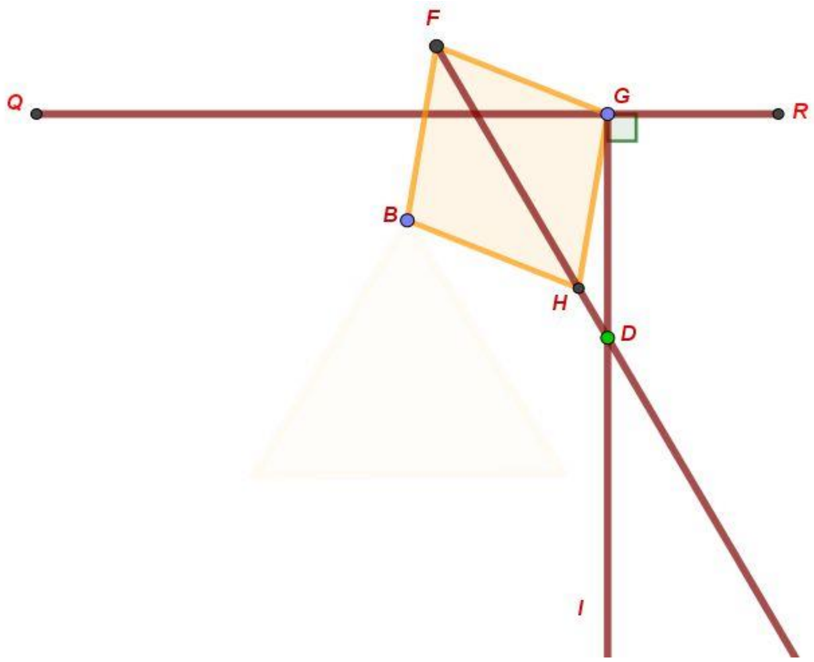
MATHEMATICAL MACHINES are special types of modular systems.
They are artefacts designed - usually by a mathematician - so that their articulated parts move and draw lines **following a mathematical law.**
By studying the mathematical machine and its movement, **we try to discover the ''hidden'' law.**
The mathematical machine you see is a machine made by the mathematician Frans van Schooten (1615-1660).





Imagine a man holding the machine that is lying on a table. He is holding the machine with one hand, while his other hand - the hand you see on the G-joint – pushes towards left.
Pushing to the left, the G point drifts the vertical bar (GI).
The Point B is nailed to the table and fixed.
The horizontal bar is also nailed.
A pen that is placed at the point D, draws a line.
On the right side of the picture you can see a modern reconstruction of the **van Schooten's machine.**
(The large triangle was added to keep the construction stable. It does not play any role in the function of the machine, and we are not going to include it in our work).

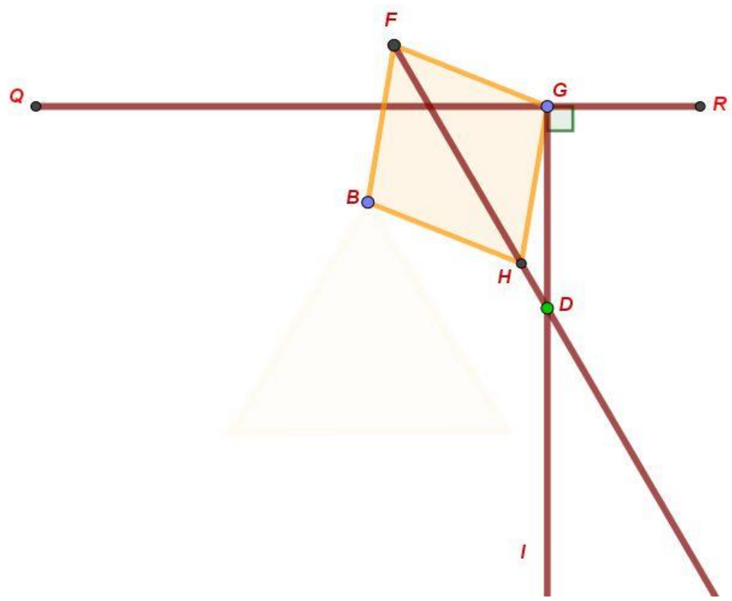
You see a geometric representation of the machine.



(1) What geometric shapes, and generally what geometric objects can you recognize in this representation?

(2) Write down and justify any relation that you can find.

(3) From the relations that arise, can you conclude something about the D point?



(4) The quadrilateral that exists in this system, what kind of quadrilateral is and why?

(5) Compare the triangles FBH and FGH. What are your conclusions?

(6) Compare the triangles BHD and GHD too. What are your conclusions?

(7) Which property of the point D is "unchanged" while the point G is moving?

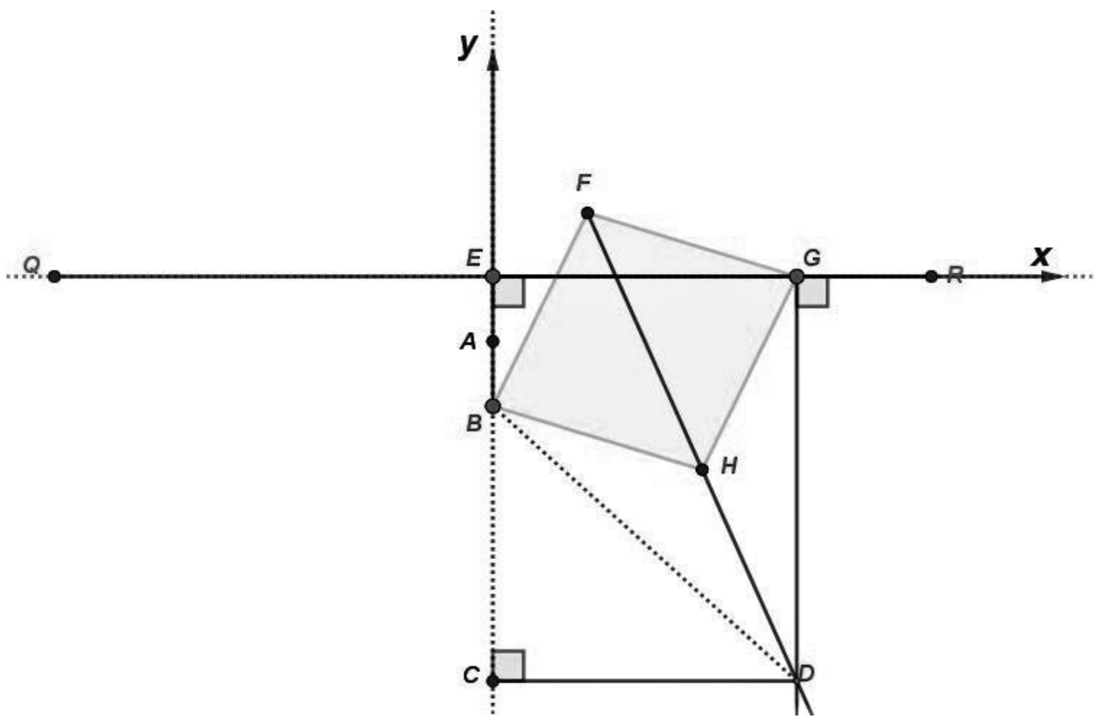
READ AGAIN THE FIRST QUESTION at the warm-up phase.

Can you now add more points to your answer? Justify your answer

Phase B'

In the figure below, we have placed Cartesian coordinate system axes

(1) Find the coordinates of the points **G & C**, if the fixed/immovable point **B** has coordinates **(0, -p)**, where **p = positive constant number,** and the point **D** has coordinates **(x, y).**



(2) Apply the Pythagorean theorem to the **BCD triangle** using the coordinates of points **B, C, D and G.**

(3) What relationship results (and links) for the coordinates of point D?

Formulate it and comment on it. Does it remind you of any well-known function?

(4) Can you formulate a hypothesis on what kind of line would a pencil placed at point D draw? What is your reasoning for this hypothesis?

(5) What is the meaning of the constant term in the relationship you found?

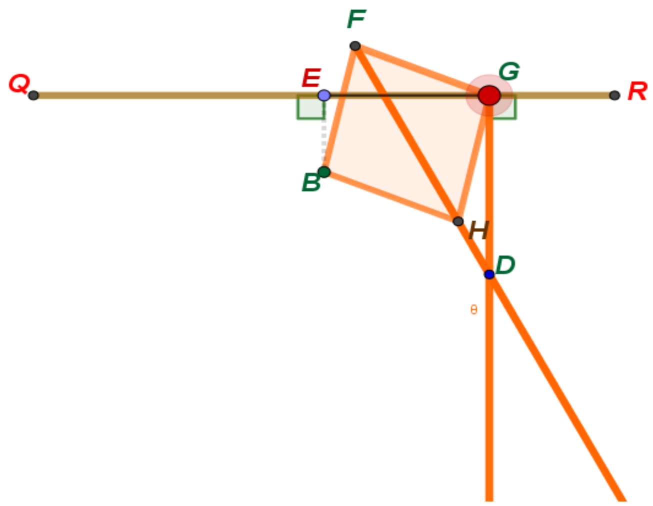
(6) What does the minus sign of the constant term mean?

(7) What does the negative coefficient of x^2 mean?

(8) What will happen to the coefficient of x^2 if the distance p is increased?

(9) What is the impact of this on the line that the machine is drawing?

VERIFICATION USING THE MACHINE



(1) Put the pen on point D and turn on the mathematical machine. What kind of line does it draw?

(2) Move the point B of the machine, bringing it closer to point E.

Then drag the point G along the QR bar. What is the difference between the line being created now and the one you found before?

Justify your answer using the relationship between the coordinates of the point D that you found in a previous query.

(3) Move the point B at a distance from the point E **larger than the initial distance**. Drag the point G along the QR bar. What is the difference among the line that is created now and the two previous ones?

Justify your answer using the relationship between the coordinates of the point D that you found in a previous query.

VERIFICATION USING GEOGEBRA

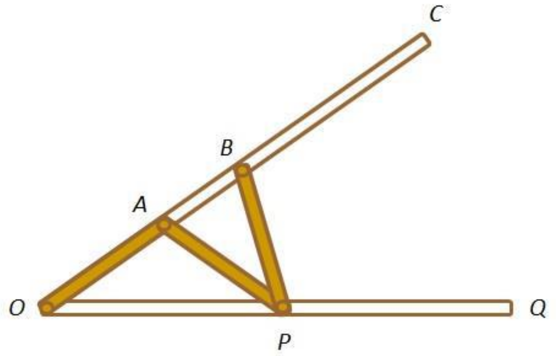
VERIFICATION PHASE

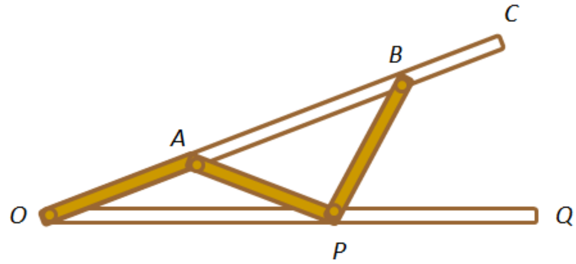
Open the "Van Schooten.ggb" file located on the desktop of the PC that is a simulation of the Van Schooten machine.

Move the point G (holding the left mouse button firmly) to make the machine moving.

MECHANICAL ANGLE TRISECTOR of E. PASCAL (1588-1651)

WORKSHEET

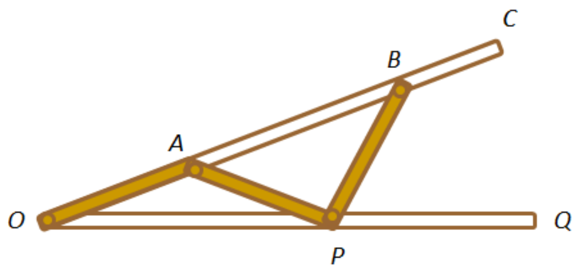




ACTIVITY 1

On the right you can see a mathematical machine that was invented by E. Pascal in order to solve one of the unsolved problems of the ancient world that were 'troubling' the mathematicians (and not only them): *trisecting an angle*.

In this machine, the rods OA, AP, PB, have the same length.



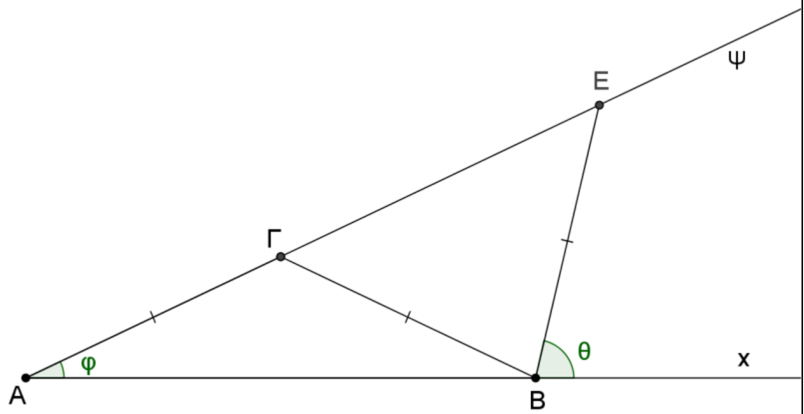
1. Which geometrical shapes and which geometrical properties can you recognize? Explain.
2. Based on your observations, draw the corresponding geometrical shape using your geometrical tools. Describe in detail and accurately the steps for your design.

ACTIVITY 2

1) Your sketch should be similar to the one is shown on the right.

For the sketch on the right it applies that: AΓ=BΓ=BE.

Find the relationship between the of angles $\chi\widehat{B}E$ and $B\widehat{A}\Gamma$ justifying your opinion.



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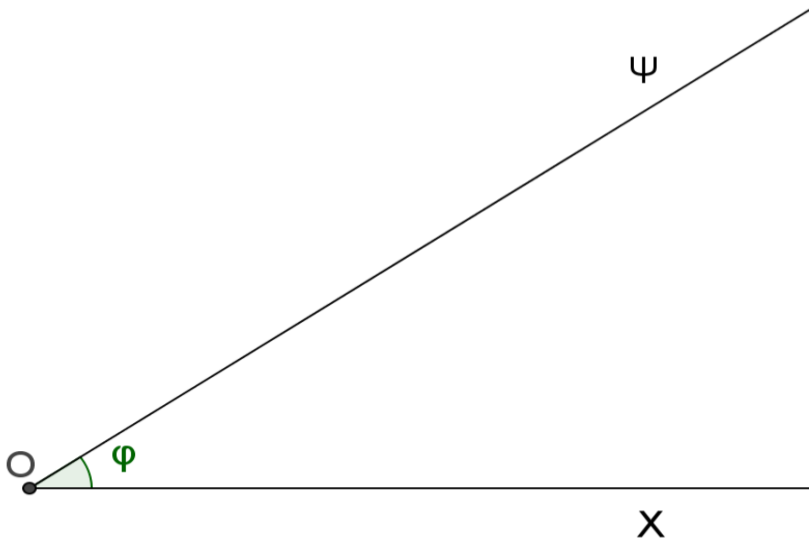
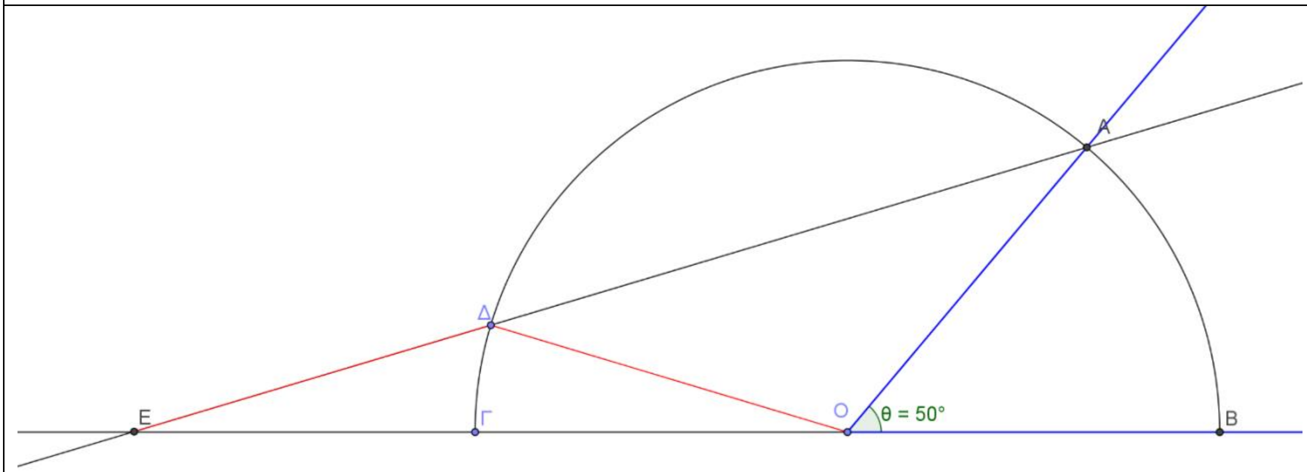
Relationship:	Justification:

<table>
<tr><th colspan="2">ACTIVITY 3</th></tr>
<tr><td>Based on the above, can you divide the angle of the figure into three equal parts?

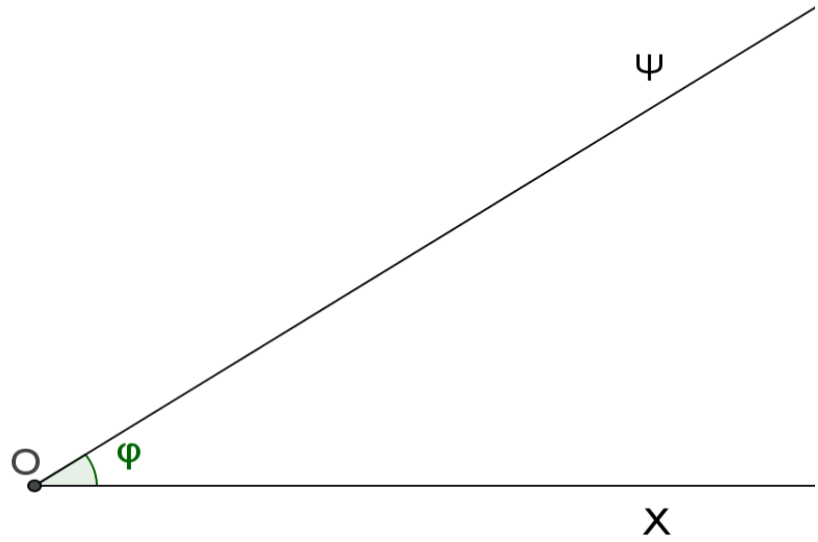
REMEMBER
USING ONLY A RULER KAI A COMPASS</td><td>

If you didn’t manage it, go to the next exercise.
Before you finish you may manage to trisect the angle</td></tr>
</table>

ACTIVITY 4 - IN THE STEPS OF ARCHIMEDES



$B\widehat{O}A = 50^0$ In the figure above the angle is encircled in a circle with center O and radius OB. The straight line EA intersects the semicircle at point Δ so that EΔ=OB. Calculate the angles of the figure.	Calculations:

ACTIVITY 5	
Based on the above, can you divide the angle of the figure into three equal parts?	
Describe the procedure step by step:	

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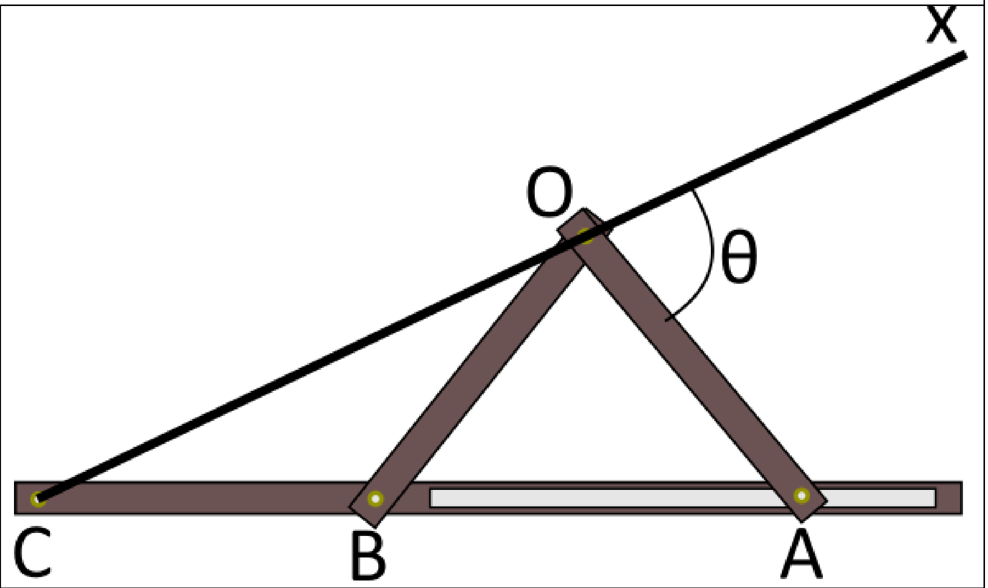
<table>
<tr><th colspan="2">ACTIVITY 6</th></tr>
<tr><td rowspan="2">The figure on the right is a representation of the device made by the Italian mathematician Giovanni Ceva.
It consists of three rods, OA=OB and CA. The CA rod has a groove where the end point A of the rod OA can be moved on a straight line.
Also, CB=OB=OA.
$x\widehat{O}A = \theta$Consider the straight line that joins the points C and O and that</td>
<td>
</td></tr>
<tr><td>1. Draw with your geometric tools the geometric figure:

2. Recognize and write down all the geometrical shapes of the machine. What properties do they have?

3. Calculate all the angles of the figure.

4. What do you think the above device does?</td></tr>
</table>

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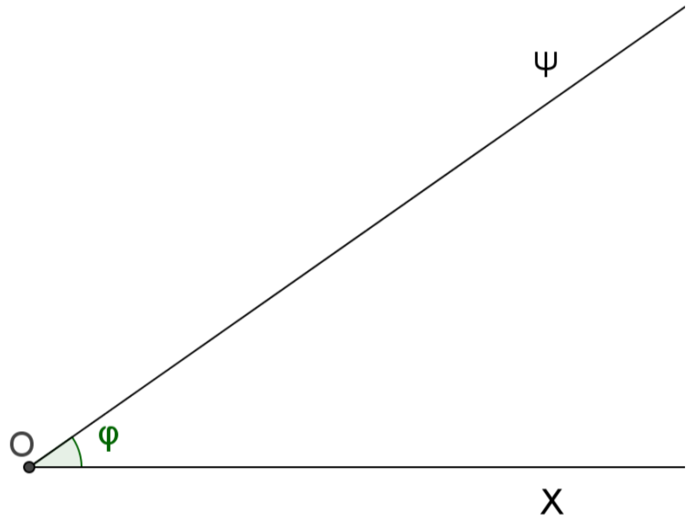
ACTIVITY 7

Let suppose you have been given the angle on the right and have been asked to trisect it.



Can you use the mechanism of the previous activity and if so, how? Describe the procedure in steps:

Step 1°

Step 2°

Step 3°

Step 4°

ACTIVITY 8

Draw an angle the size of which is fitting in the size of an A4 page. Trisect the angle using the machine.

MECHANISM TO REPRODUCE SCHEMES IN DIFFERENT SCALE

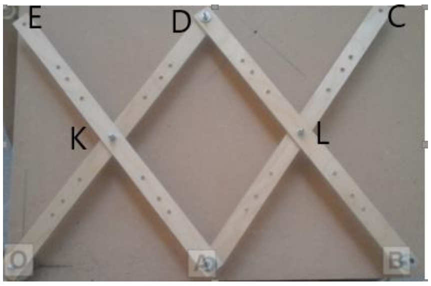
Pantograph of Christoph Scheiner (1573-1650)

How can we change the size of a shape, without changing its form?

ACTIVITY 1

THE SCHEINER'S PANTOGRAPHE

You have at your disposal a wooden version of Scheiner's pantograph. The wooden sticks bear holes and are connected in every two of them with metal screws, thus creating joints that allow to change the form of the pantograph.



The end of one of the pantograph's sticks (O, in the picture) is bound to the wooden surface, and around that, the system can pivot. It also bears two wooden styluses, one at joint A and one at the free end B.

When one of the stylus (driver -point) follows a rout, then the next stylus (trace-point) is forced to follow the first's ones movement and is thus tracing a similar track.

Experiment – Explore – Form assumptions – Explain-Prove

How is the machine made?

1) Identify the type of quadrilateral that the four joints A, L, D και K of the mechanism formed. Explain your reasoning.	

<table>
<tr><td rowspan="2">2) Identify elements of the pantograph that change and elements that remain unchanged when one of the pens moves freely on the plane.</td><td>Changing elements</td><td>Unchanged elements</td></tr>
<tr><td></td><td></td></tr>
<tr><td>3) Make a figure that it represents the shape of the pantograph and that provides information about the elements of its structure.

Describe in detail the steps that you followed when designing.</td><td colspan="2"></td></tr>
</table>

4) Prove that points O, A and B, which are representing the positions of the axis of rotation and of the two pens in your drawing, are collinear.	
5) Determine the relationship of the distances of A and B pens from the pivot axis O. Justify your answer.	

ACTIVITY 2	
What does the machine do and why?	
Experiment – Explore – Form assumptions - Explain	
1) Draw a straight segment on the pantograph board surface a) Move the pen A along the straight segment that you designed. What is the figure of the other pen B? Compare the two figures (straight segment and its image). What do you notice? Formulate a conjecture	**ANSWER**
b) Move the pen B along the straight segment that you designed. What is the figure of the other pen A? Compare the two figures (straight segment and its new image). What do you notice? Formulate a conjecture c) Find the relationship between the straight segment that you designed with its two pictures.	**Answer** Relationship:

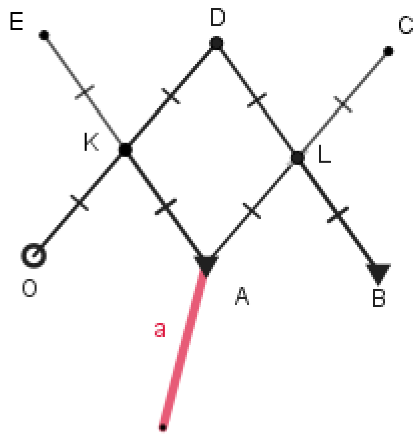
2) In the next figure, you can see a geometric representation of your previous work with the pantograph, in case that the pen A moves along the straight segment that you were designing.

a) Complete the drawing with the figure that the pen B produces.

b) Describe the procedure that you followed to design the figure produced by the pen B on the drawing.

c) Find the relationship that you have drawn from B with straight segment ***a.*** Justify your opinion.

d) Justify the relationship between straight segment **a** and the figure produced by B based on the structure of the pantograph.



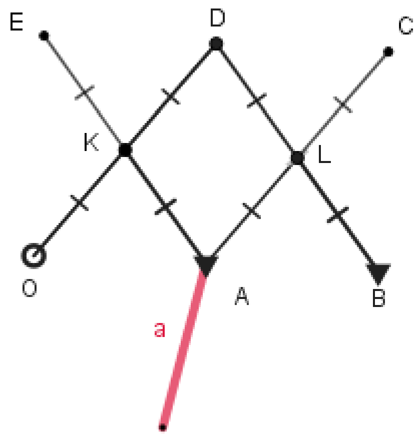
3) In the next drawing, you see a geometric representation of the pantograph and a straight segment ***a*** along which the pen A can move.

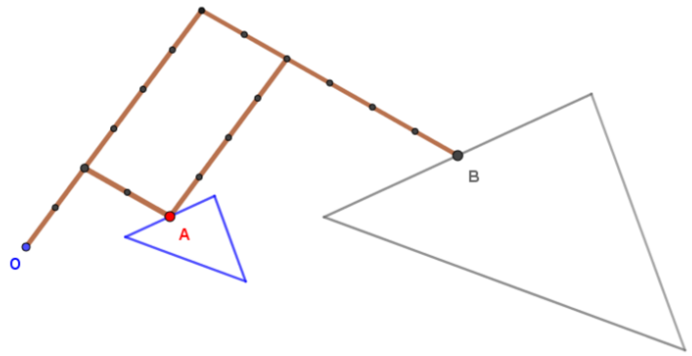
a) Draw a triangle that it has a straight segment ***a*** as its side.

b) Draw the figure that the pen B will produce when the pen A moves around the perimeter of the triangle that you designed.

c) What can you say about the two triangles?

Justify your answer.

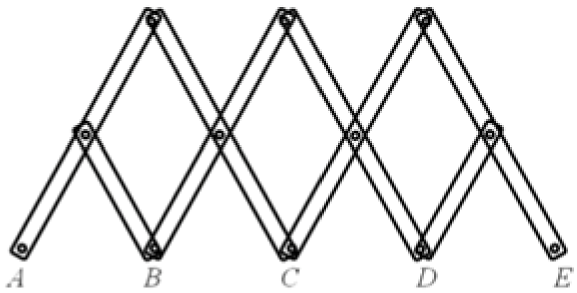


<table>
<tr><th colspan="2">ACTIVITY 3</th></tr>
<tr><th colspan="2">What does the machine do and why?</th></tr>
<tr><td colspan="2">Experiment – Explore – Form assumptions – Explain- Prove</td></tr>
<tr><td>The next picture represents a simplified version of another version pantograph of Scheiner.
a) What is the relationship between the two triangles?
b) Justify your answer by based the pantograph's structure.</td><td>
</td></tr>
</table>

ACTIVITY 4	
Modifying the Pantograph	
1) Design a model pantograph that quadruples the original shape. Explain how you thought to do your figure.	
2) Design a model pantograph that triples the original shape. Explain how you thought to do your design.	
3) *Can a pantograph reproduce a shape without changing its shape and size?* Explain how you thought to do your design. If so, design a model of such a pantograph.	

ACTIVIT 5

In the next picture we see the schematic representation of a pantograph model, which can reproduce copies of an image with different scales by changing:
-the position of the fixed point that acts as the axis of rotation,
-the driver-point describing the original image and
-the tracer-point produces the copy of the original image.
Complete the table.



Pivot point	Driver-point	Tracer-point	Scale factor
A	B	E	4
A	C		1.5
A	E	B	
A			2/3
A	D	E	
	C		3

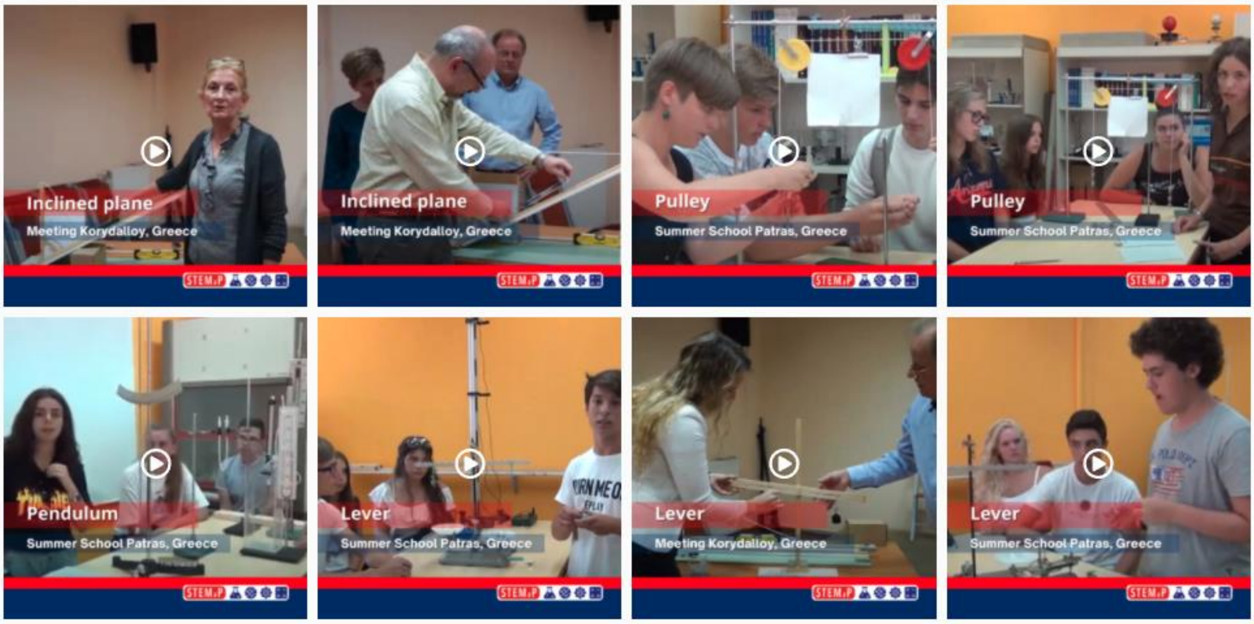
Annexes 5 – STEMAP Videos

www.stemap.eu/video-gallery

More laboratory videos will be added to the video gallery during the project implementation and beyond its closure.

VIDEO GALLERY

All videos | Experiments | Kick off Meeting | Meeting Korydallos (EL) | Laboratories



All videos | Experiments | Kick off Meeting | Meeting Korydallos (EL) | Laboratories

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