ASTROEDU

Peer-reviewed Astronomy Education Activities

The gravity battle

Who will win in the epic battle between gravity and other forces?

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KEYWORDS

tinkering, magnetism, normal force, force, friction, Physics, Archimedes principle, gravity, hands-on

CATEGORY

<QuerySet [<SciCategory: Gravity and relativity>, <SciCategory: Physics>]>

LOCATION

Does not matter

AGE

8+

LEVEL

<QuerySet [<Level: Informal>, <Level: Middle School>, <Level: Primary>, <Level: Secondary>]>

TIME

1h

GROUP

Group

SUPERVISED

No

COST

Low Cost

SKILLS

<QuerySet [<Skills: Asking questions>, <Skills: Constructing explanations>, <Skills: Engaging in argument from evidence>, <Skills: Planning and carrying out investigations>]>

TYPE OF LEARNING

<QuerySet [<Learning: Fun activity>, <Learning: Guided-discovery learning>, <Learning: Observation based>, <Learning: Other>, <Learning: Structured-inquiry learning>]>

MATERIALS

Material needed for the activity (see activity for preparation)

- Wooden cubes
- Nails, Copper wire and aluminum foil to prepare the "metallic cubes" (see description of activity)
- Water containers
- Shoe boxes
- Magnets
- Glue
- Sheets of paper
- Inclined plane painted along one-half (see description of activity)

GOALS

Discovering physical processes through hands-on activities, developing teamwork skills and the ability to express ideas.

LEARNING OBJECTIVES

- What is gravity
- Buoyant force
- Friction
- Magnetic force
- Normal force
- How forces act in contrast with each other.

BACKGROUND

Gravity is the force that causes all massive objects in the universe to attract each other. Light has no mass, but it still experiences the effects of gravity, which can curve its trajectory. This force explains why planets orbit stars and also why objects fall here on Earth. As Isaac Newton discovered, the force attracting Earth to the Sun is the same force pulling an apple toward the ground, and that force is gravity. However, some other forces can counteract the action of gravity by acting in the opposite direction. For example, the buoyant force comes into play whenever a body is immersed in a fluid (not just in water, but also in air!). This force opposes gravity, and its intensity is determined by the weight of the volume of fluid displaced by the body. The crucial aspect is density: if the density of the body is greater than that of the fluid, gravity is more intense than the buoyant force, and the body sinks. In the opposite case, the buoyant force is more intense, and the body floats. For a sketch, see Figure “background1”.

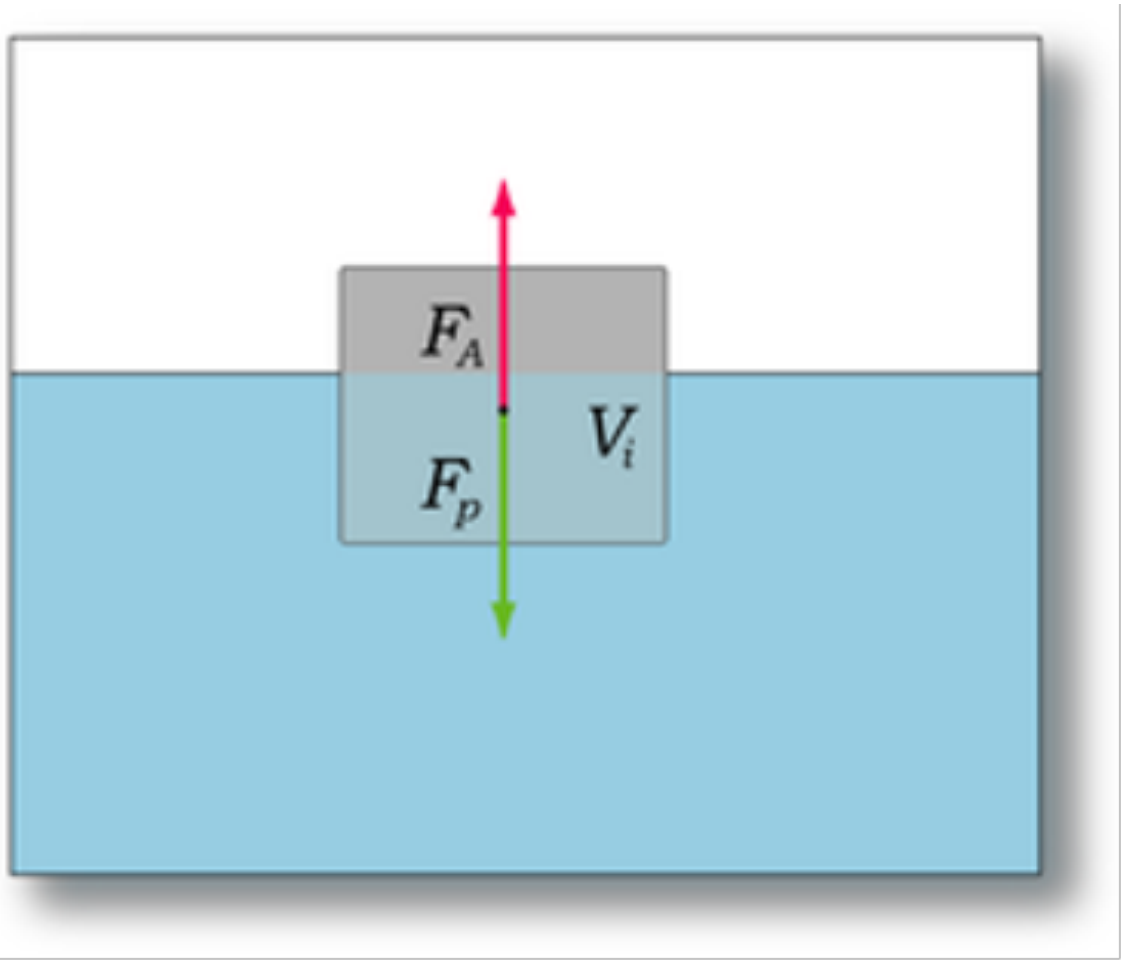

Figure 1: Sketch of the buoyant force acting on a cube in water.

Friction is a force that arises between bodies in contact. One of the aspects it depends on are the materials the bodies are made of. Smooth materials generate less friction, while rough materials generate more friction. The shape of the bodies also plays a role: friction behaves differently on square-edged bodies (sliding friction) and rounded ones (rolling friction). Objects in free fall are also affected by air resistance, which generates friction upon contact with the air. In this experiment, we are dealing with friction between solids. The friction between a body and a surface is also proportional to the mass of the body and, in the case of an inclined plane, it decreases as the inclination of the plane increases. Key parameters for this force: mass of the body, materials, inclination of the plane. For a sketch, see Figure 2.

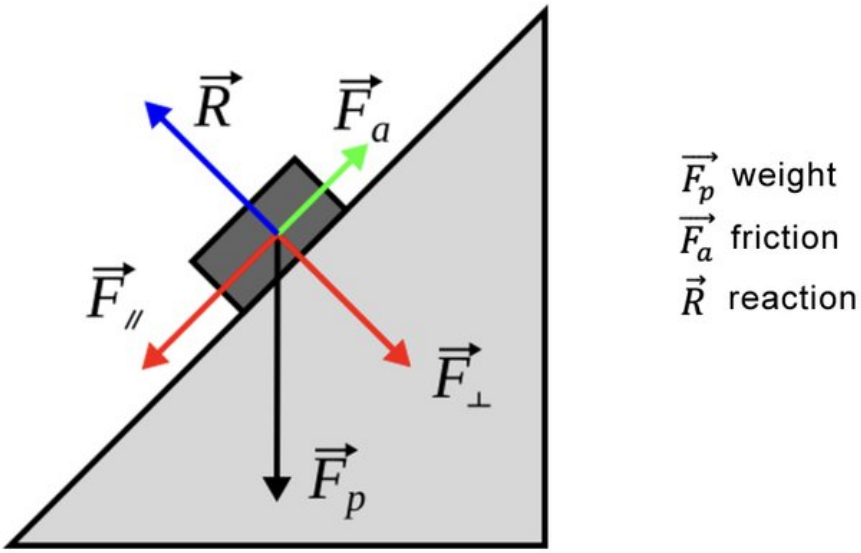

Figure 2: Sketch of friction acting on a cube on an inclined plane.

The magnetic force acts on materials with magnetic properties, such as iron, cobalt, nickel, etc., and also on some alloys of magnesium, chromium, and uranium. Objects made of such materials are attracted to sources of magnetic forces. However, in the case of magnets, the situation is more complex. Magnets have two poles: opposite poles attract each other, while like poles repel. Unlike the other forces we have seen, the magnetic force also acts at a distance, but its strength decreases as the distance increases. Key parameters for this force: materials, distance. For a sketch, see Figure 3.

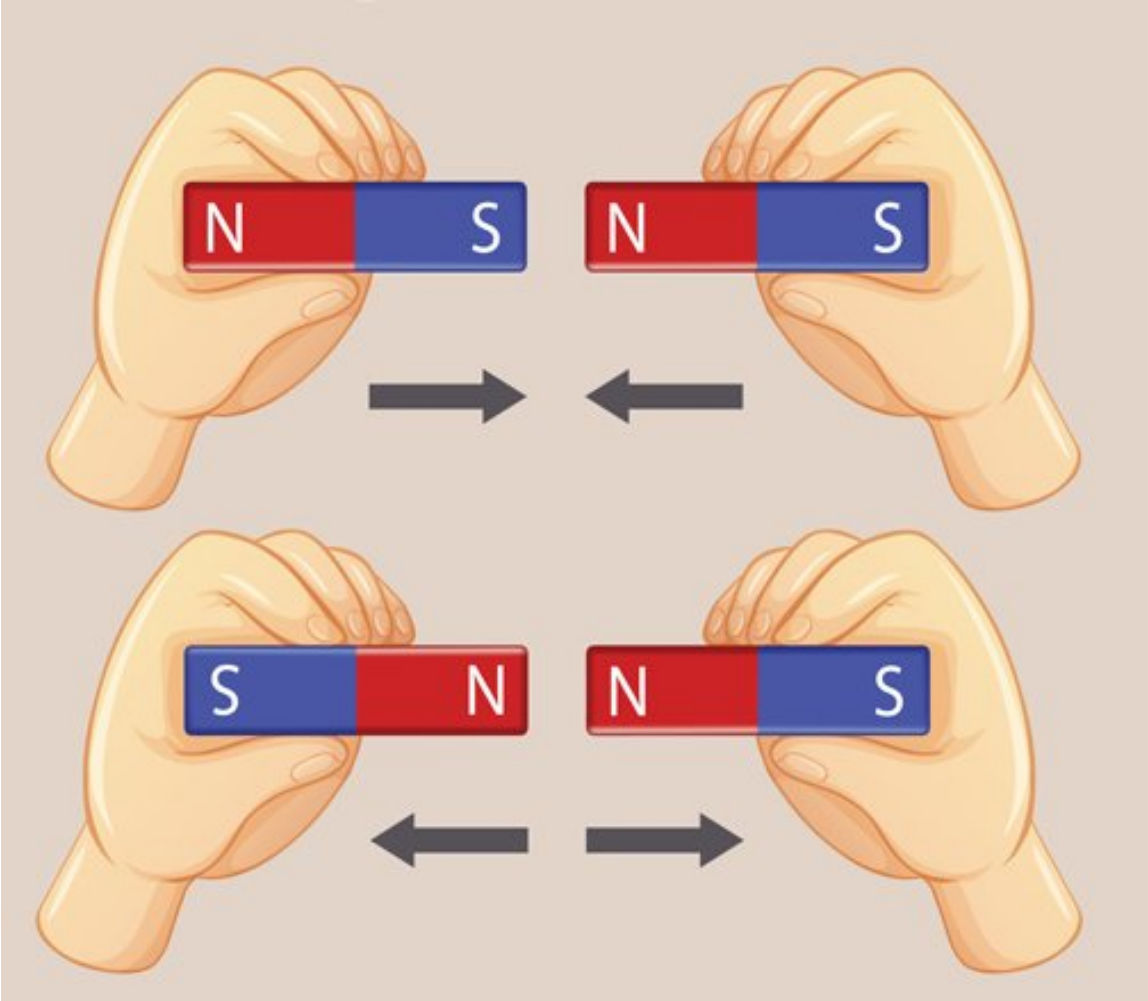

Figure 3: Sketch of the magnetic force acting between two magnets. Credits: Vecteezy

The normal force arises whenever a body tries to resist deformation. The body resists until the force causing the deformation exceeds its breaking point. When an object is placed on a surface, it tends to fall due to gravity and, therefore, it deforms the surface. Hence, the surface develops a reaction force that opposes gravity as long as it is strong enough. However, if the weight of the body exceeds the breaking point of the surface, it will break. In some cases, it is possible to enhance the resistance of a surface by modifying its geometry: folding a sheet upon itself is a simple way to make it more resistant. Key parameters for this force: breaking point and surface geometry. For a sketch, see Figure 4.

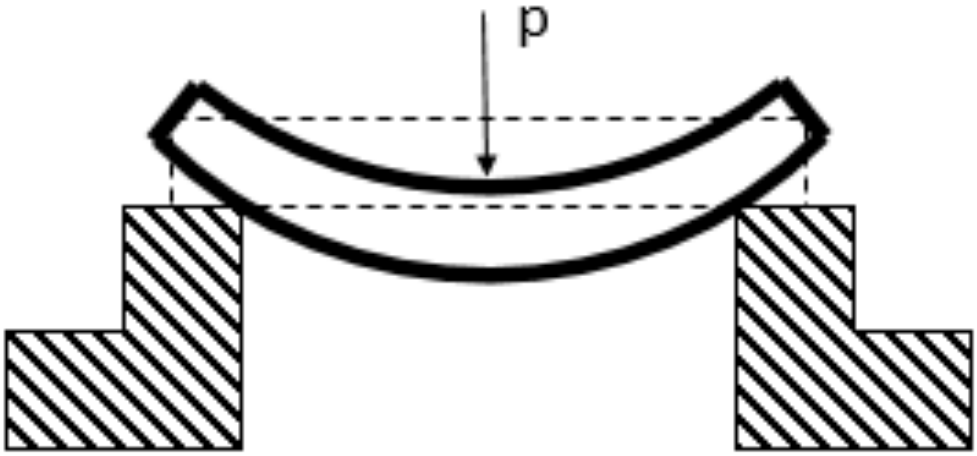

Figure 4: Sketch of the normal force acting on a surface lying on two supports.

FULL DESCRIPTION

During this activity, participants will experience the contrast between gravity and other forces. The activity consists of four 'stages,' and in each of them, gravity will "compete" with one of the following forces:

1. Stage1 - Buoyant force
2. Stage 2- Friction force
3. Stage 3- Magnetic Force
4. Stage 4- Reaction Force

At the end of the guided activity, students can be asked to experience forces on their own on a Tinkering table.

Preparation

Preparation of "metallic cubes": half of the wooden cubes are prepared with 12 nails (2 nails for each face of the cube), covered with copper wire, and then with an aluminum layer. These are the the 'metallic' cubes referred to in the text. (See Figure 5)

Figure 5: preparation of the metallic cube

Buoyant force stage: put the boxes on the table, far enough from the edges and from each other. Then put water into each box up to 4 cm from the top of the box.

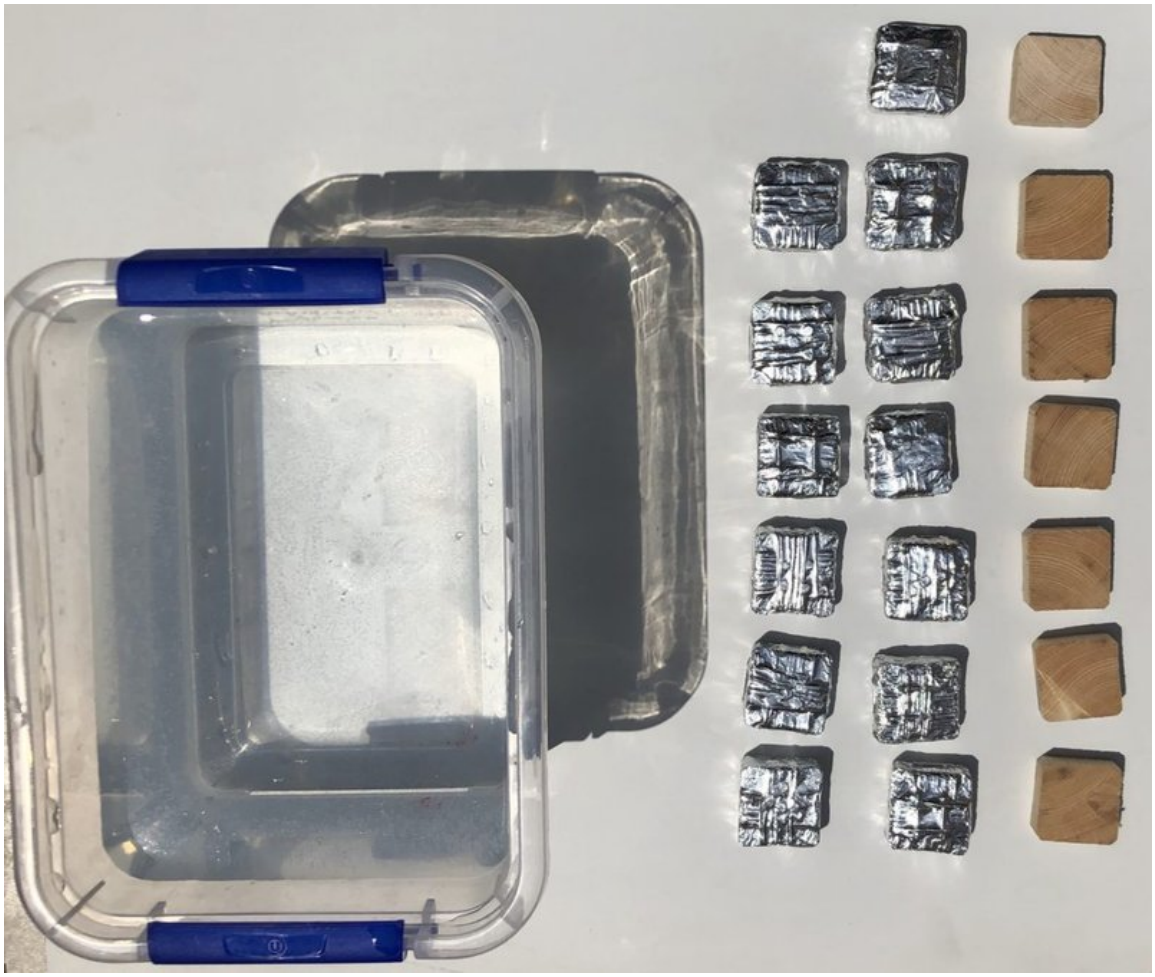

Figure 6: material prepared for stage 1 - Buoyant force

Friction stage: place the inclined plane on the table and secure it with something stable (rocks work well; alternatively, try to keep the plane steady with your hands). Initially, the plane should have a low inclination (Figure 7).

Figure 7: Set-up of the inclined plane used for Stage 2 - Friction force.

Magnetic force stage: remove the lids from the shoeboxes and place the boxes on the table, using the smaller face as the base. Then, fix the magnets to the inner side of the upper face using glue (Figure 8).

Figure 8 : Set-up of the box with magnets used for the Stage 3 - Magnetic force.

Normal force stage: place two shoeboxes (with lids) on the table, using the larger faces as the base. Keep some sheets of paper within reach as well.

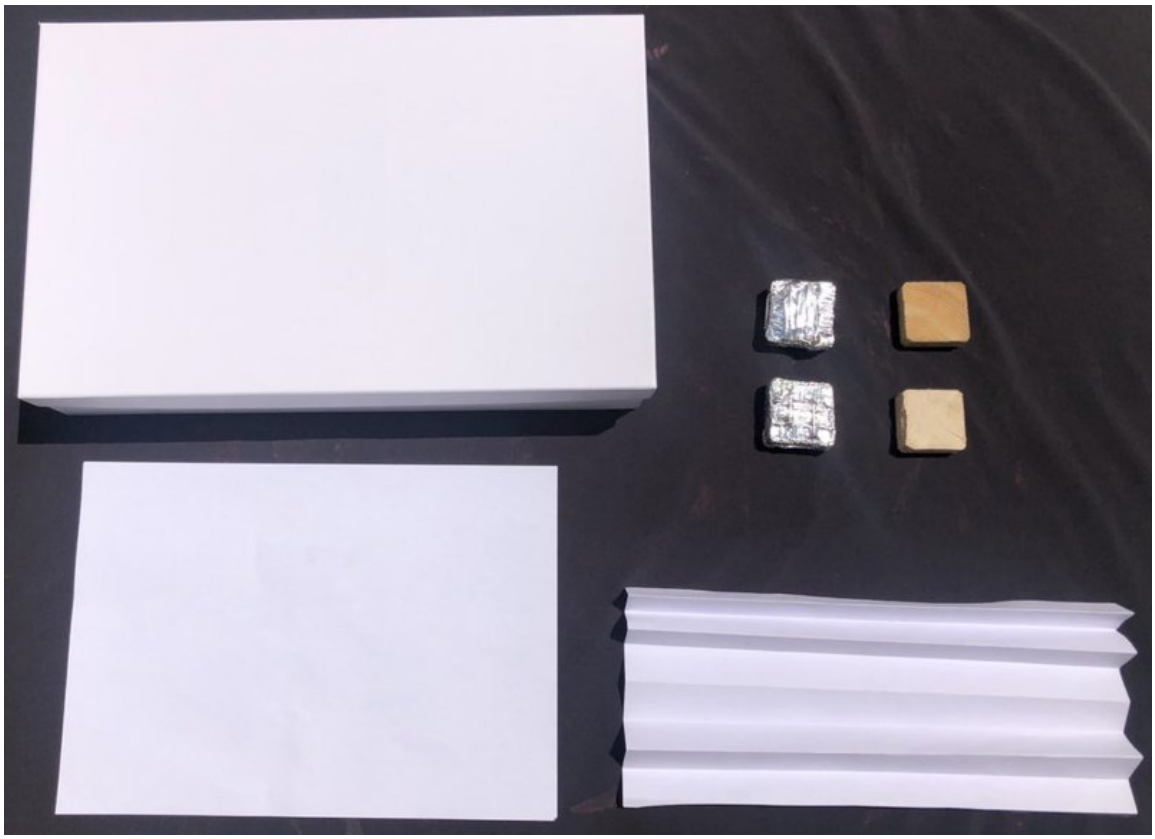

Figure 9 : Material needed for the Stage 4- Normal foce

Figure 10 : Set-up for Stage 4 - Normal force.

Beginning of activity

Every participant receives from the teacher one wooden and one "metal cube". The teacher explains the activity, telling the participants that there is a "tug-of-war" between gravity and other forces, and that they will discover in which cases gravity wins and in which cases other forces win.

Stage 1- Buoyant force

The teacher briefly introduces the buoyant force and asks the participants to put the wooden and metal cubes in water (Figure 11) to demonstrate how the force acts on different materials.

Figure 11 : Buoyant force in action

The teacher can ask the students to observe the phenomenon and reflect on what they see:

- What happens? (the wooden cube floats, while the metal one sinks)
- Why? (the buoyant force overcomes gravity as wood has a lower density than water. But the opposite occurs for the metal cube).

Stage 2 - Friction

The teacher briefly introduces friction, and then asks the participants to try dropping both their cubes along the inclined plane, using only the unpainted part (Figure 12). The metal and wooden cubes fall at different speeds because friction depends on the materials.

Figure 12 : Friction in action: two cubes falling down the unpainted part of the inclined plane.

Reflect on what you observe:

- What happens? (the cubes do not fall)
- Why? (friction is stronger than gravity, as it is made stronger by the tilting of the plane)

Now let's make friction weaker by increasing the inclination of the plane, until the cubes start falling. Now gravity wins. However, cubes fall slowly: the teacher asks the participants to check if this fall is slower than the free fall (it is). The teacher can also ask the students to observe what cube falls more quickly (the metal one) and highlight that friction depends on the materials involved.

The teacher can also ask participants to place their wooden (or metal, as long as they are of the same material) cubes on the two different parts of the plane (Figure 13): one cube on the painted part and one on the unpainted part, at the same height, and let them fall. Even though the cubes have the same weight, the one falling along the painted part of the plane is slower because the paint increases the friction on the plane.

Figure 13 : Friction in action: one cube falls down the unpainted part of the inclined plane, while the other one on the painted part.

Stage 3 - Magnetic force

The teacher briefly introduces the magnetic force, then asks the participants to place the cubes against the inner side of the upper face of the box (where the magnets are glued) and to let them fall (Figure 14). We can observe that the magnetic force only acts on metals.

Figure 14 : Magnetic force in action.

Stage 4 - Normal force

The teacher briefly introduces the normal force, then places the lid of one of the boxes as a bridge between them and asks the participants to put the cubes on top (Figure 8).

Figure 15 : Normal force in action using the show box lead.

The cubes do not fall. Afterward, the lid is replaced with a sheet of paper. The cubes fall (Figure 9).

Figure 16 : Normal force in action using a sheet of paper.

At this point, participants can be asked how to make the paper more resistant. They may discover that folding the paper can make the sheet strong enough to prevent the cubes from falling (Figure 10).

Figure 17 : Normal force in action using a folded sheet of paper.

EVALUATION

As an evaluation, you can propose a "tinkering table", a table where students will find all the materials they used in the experiments of this activity. All participants gather at the tinkering table, where they can have fun and experiment with the cubes, paper, magnets, and all the available objects, applying what they have learned. You can evaluate the ability of participants to reproduce what they learned through the materials available.

Their ability to describe the effects of the various forces through a group discussion and/or a written test can also be evaluated.

CURRICULUM

Science, physics, maths.

FURTHER READING

Archimedes principle

Friction

Magnet

Normal force

CITATION

; ; , 2024, *The gravity battle*, astroEDU, 2405

ACKNOWLEDGEMENT

This activity was developed within the AMACA (Astronomy education with a Multisensory, Accessible, and Circular Approach) project