TEMI

The Book of Science Mysteries

The curved light

CLASSROOM SCIENCE ACTIVITY TO SUPPORT STUDENT ENQUIRY-BASED LEARNING

This classroom-tested teaching plan uses the four innovations of the TEMI project, as detailed in the Teaching the TEMI Way (TEMI, 2015).

You should read this companion book to get the most from your teaching. The **TEMI** techniques used in this teaching plan are: **1)** productive science mysteries, **2)** the **5E model** for engaged learning, **3)** the use of presentation skills to engage your students, and **4)** the apprenticeship model for learning through gradual release of responsibility. You might also wish to use the hypothesiser lifeline sheet (available on the **TEMI** website) to help your students document their ideas and discoveries as they work.

To know more about **TEMI** and find more resources **www.teachingmysteries.eu**

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teachingmysteries.eu

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The curved light

What's the mystery?

Light rays propagate rectilinearly, as can be seen with micro-particles of powder, talcum powder, or smoke in a medium with a laser beam.
Why is the laser light in the Plexiglas pan filled with water curved?

DOMAIN(S)

Physics.

SUBDOMAIN KEYWORDS

Refraction of light.

AGE GROUP

12 to **18** years old.

EXPECTED TIME FOR THE MYSTERY

Approximate time for teacher preparation:
Two hours.

Approximate time in classroom:
Three or **four** individual **50 min.** lessons**.**

SAFETY/SUPERVISION

Laser pointers have to be handled with care and never directed at people's eyes.

Disclaimer: the authors of this teaching material will not be held responsible for any injury or damage to persons or properties that might occur in its use.

PREPARATION AND LIST OF MATERIALS

- Laser pointers
- Talcum powder
- Plexiglas semicylinder
- Glycerol
- Water
- Sugar syrup
- Milk
- Mineral oil
- Alcohol
- Water tanks.

To prepare the mystery, put about 8 cm of glycerol (better) or sugar syrup at the bottom of the Plexiglas pan and then add water without stirring. After about one hour of rest (it can work better after some hours or even after days), a density gradient of glycerol will be present in the pan. Throw the light of a green laser beam longitudinally through the pan near the interface between the glycerol and the water; adjusting the direction of the beam, you will see it curved towards the bottom. To better visualise the trajectory of the light, add a touch of skimmed milk to the two liquids.

LEARNING OBJECTIVES

- Qualitative behaviour of light when the medium in which it propagates changes its refraction index.
- Quantitative evaluation of the behaviour of light in refraction by means of Snell's law.

Guidance notes for teachers

THE 5E MODEL

Engage

CAPTURE STUDENTS' ATTENTION

Carefully point a laser beam in different directions and through different media all around the class (be careful of reflections: lasers are dangerous, so do not point them at people's eyes). Use some talcum powder to visualise the straight beam in the air. When you direct the beam through water, transparent oils, glass prisms, etc., you will see a rectilinear propagation of the beam.

Now continue your observations by directing the laser pointer into what looks like a simple Plexiglas pan of water; in reality, this will contain also some glycerol. Watch the beam as it mysteriously curves. Why is this?

Explore

COLLECT DATA FROM EXPERIMENTS

Students may build their own experiments to investigate the trajectory of the light by using laser beams and different transparent materials such as glass, Plexiglas, water, transparent oils, and others. Once they have understood something about light's behaviour when it passes through the surface of separation between two different media (the teacher will then introduce the word refraction), they will be ready to investigate diffraction in cases where the refraction index changes continuously. It is then possible to create refraction index gradients by adding water to glycerol.

Explain

WHAT'S THE SCIENCE BEHIND THE MYSTERY?

When a light beam goes through the medium in which it propagates, its direction changes. If the optical density of the medium contains a gradient, the direction of the beam changes continuously and the trajectory appears curved. The optical density may be varied by putting sugar syrup or glycerol at the bottom of a Plexiglas pan and then adding water without stirring. After some time (the longer the duration, the better the effect) a density gradient of glycerol will be present in the pan.

A second step in the explanation can be the description of Snell's law of refraction in mathematical terms.

Extend

WHAT OTHER RELATED AREAS CAN BE EXPLORED?

Refraction of light may explain many optical effects, like, for example, what happens to a straight object that appears bent on the surface of the water when it is submerged. Lenses are another immediate extension, as are cosmological gravitational lenses: these provide a very intriguing (and complex) topic that can be introduced by means of an analogy with refraction. This could interest students who are older than 14.

Evaluate

CHECK THE LEVEL OF STUDENT SCIENTIFIC UNDERSTANDING

Students should now be able to predict, at least qualitatively, the trajectory of light in simple experimental situations.

Teachers may prepare some particular spatial variations in different media, such as prisms or liquids with different optical indexes; when doing this, the teacher can ask students to predict the trajectory of light.

If students' knowledge is such that they have already understood the topic quantitatively, then it will be possible to ask students to make quantitative predictions.

THE 5E MODEL

Showmanship

TIPS ON HOW TO TEACH AND PRESENT THIS MYSTERY

Showmanship in the presentation of the mystery is mainly focused on how the behaviour of light in the classroom is demonstrated. Darkness is fundamental. The laser lights (typically red and green) will also have to be projected normally after talcum powder is dispersed in the room. Students will therefore recognise the straight propagation of the laser beam and will be surprised at seeing the laser beam curve in the liquid contained in the pan. Wordy descriptions are not needed because the light beams speak for themselves dramatically.

GRR

TEACHING SKILLS USING GRADUAL RELEASE OF RESPONSIBILITY

Setting up the mystery: if light goes straight wherever we visualise it in the room, why does it curve in this pan?

Demonstrated enquiry (level 0).
Teacher-as-model: you show the students how to carry out an enquiry process by explaining your hypothesis and tests by 'talking aloud', which students then copy. The students record your thinking onto their hypothesiser lifeline worksheet. The teacher will start with the rectilinear propagation of light, observing that if the medium (he/she can try water, mineral oil, glycerol, alcohol, glass, Plexiglas, etc.) in which the light propagates is uniform, the light doesn't change its direction. Subsequently, the teacher will show what happens on the surface of separation between the two different media. From this last observation, the teacher will describe qualitatively what makes the trajectory of light curve.

Structured enquiry (level 1).
'We do it'. Students then use their hypothesiser lifeline to record their own alternative ideas about the direction of the propagation of the light. The teacher may prepare the experiments and students can record their thinking and their hypothesis.

Solving the mystery: students are led towards the explanation by using ideas about refraction and, when possible, Snell's law of refraction.

Resources

A very clear tutorial about the refraction of light can be found on the TEMI Youtube Channel:
www.goo.gl/tUDaq5
- playlist > refraction of light

In order to face the intriguing gravitational lensing, you can use the following videso on the TEMI Youtube Channel:
www.goo.gl/tUDaq5
- playlist > gravitational lensing
- playlist > what is gravitational lensing
- playlist > refraction of light

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STUDENT WORKSHEET

You have seen a red laser beam and a green laser beam that crossed the dark classroom without bending. It really seems that the light rays propagate rectilinearly.

However, how can the laser light propagating in the Plexiglas pan appear curved when the beam passes through the liquid in the pan? What is happening inside the pan?

Engage

WHAT'S INTERESTING?

Task 1: Carefully point a laser beam in different directions and through different media. Use some talcum powder to visualise the beam, but don't point it in anyone's eyes. Be careful of reflections too.

Task 2: Now make the laser light propagate inside the Plexiglas pan so that the trajectory can be seen in the larger surface of the pan. What happens to the trajectory of the laser beam?

Explore

WHAT'S HAPPENING?

Task 1: Build your own experiments in order to investigate the trajectory of the laser light as it goes through different media: glass, water, Plexiglas, transparent oils, glycerol, alcohol, etc.

Task 2: Create other experiments using two non-miscible media with different refraction indexes (ask your teacher for help with the selection of media with different refraction indexes) in the same pan: how does the beam behave?

Explain

WHAT'S CAUSING IT?

Task 1: What happens to the direction of the propagation of the light when it doesn't change the medium in which it propagates?

Task 2: Is there a property that you can reasonably imagine in a transparent medium that has something to do with the behaviour of a light beam that enters that medium from the air of the lab?

Task 3: Using a goniometer and the plexiglas semicylinder, you can try a quantitative characterisation of the phenomenon you have just found.

Task 4: Create a qualitative model that could explain the curve trajectory of a laser beam using your previous knowledge about the the concept of refraction.

Extend

WHAT'S SIMILAR?

Task 1: Recognise refraction in the optical effects all around yourself. For example, pay attention to what happens to straight objects that are partially submerged in water: they appear broken on the water's surface. You can do this yourself with a simple set-up.

Task 2: Lenses and mirages also work by means of refraction.

Task 3: Gravitational lenses are the last related topic. They are very intriguing and complex, and can be approached with an analogy to glass lenses.

Evaluate

WHAT'S MY UNDERSTANDING?

Task: Test your ability to predict the trajectory of a laser beam that propagates in different experimental situations. Conduct different experiments using prisms, liquids, or other transparent objects and guess the trajectory of the beam.