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Light and Matter –
How They Interact

BIOS4YOU
AR 2.0

BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS
THANKS TO THE USE OF AUGMENTED REALITY

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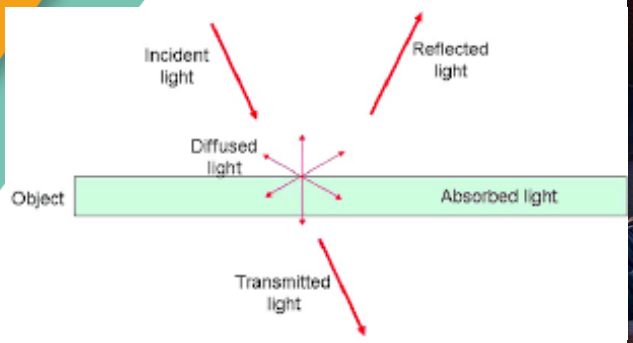

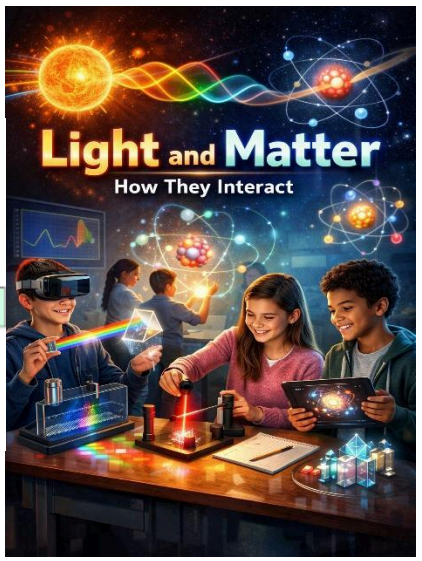

General topic of the learning path	Bio-photonics
Specific name of the learning unit	Light and Matter – How they interact
Age of the target users	15-17 years
Requirements for the learner	Students participating in this learning unit should have a basic understanding of physics concepts, particularly the nature of light and matter. They should be able to perform simple measurements, record observations, and work collaboratively in groups. Curiosity, critical thinking, and willingness to engage in hands-on experiments are essential. Learners must be comfortable using digital devices and exploring AR applications to manipulate virtual experiments. Basic skills in interpreting diagrams, tables, and graphs are required. No prior advanced knowledge of optics is necessary, but motivation to explore scientific phenomena, analyze results, and connect theory with practical observation is expected.
Description of the learning unit	This learning unit explores how light interacts with matter through reflection, refraction, absorption, and emission. Students engage in observation, hands-on experiments, and AR simulations to develop conceptual understanding, analytical skills, and collaboration. The unit fosters curiosity, critical thinking, and real-world connections between physics concepts and everyday phenomena.
Subject: Parties involved	Physics, Chemistry
Keywords	Optics Light-matter interaction, Reflection and refraction Absorption and emission

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Key qualifications, skills and knowledge that can be acquired	Conceptual Understanding: Knowledge of light properties and interactions with different materials (reflection, refraction, absorption, emission). Experimental Skills: Ability to design, conduct, and analyze hands-on physics experiments. Data Analysis: Competence in recording observations, creating tables, graphs, and interpreting results. Digital Literacy: Experience using AR tools to simulate and manipulate light-matter interactions. Transversal Skills: Development of critical thinking, problem-solving, teamwork, and scientific communication. Real-World Application: Understanding the practical relevance of light phenomena in technology and everyday life.
Resources and didactic aids used	Laboratory Equipment: Flashlights, mirrors, prisms, lenses, colored paper, glass containers, and safe laser pointers. Digital Tools: Computers or tablets for AR applications, such as Delightex Edu, Merge EDU, or Physics Toolbox AR. Visual Materials: Images, videos, and diagrams illustrating light-matter interactions. Data Recording Tools: Worksheets, tables, and graph templates for measurements and observations. Collaborative Aids: Whiteboards, posters, or shared digital platforms (e.g., Google Drive) for group discussions and reporting. Instructional Guides: Teacher-led instructions, step-by-step experimental protocols, and AR user guides.
Assessment criteria and evaluation	Active Participation: Engagement in all phases (Explore, Execute, Enhance) and contribution to group discussions. Accuracy of Observations: Correct recording and interpretation of experimental results and AR simulations.

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	Data Analysis Skills: Ability to organize data in tables, graphs, and diagrams, and draw evidence-based conclusions. Connection to Theory: Linking experimental and AR observations to underlying physics concepts of light-matter interaction. Collaboration and Communication: Effective teamwork, clear presentation of findings, and contribution to group reports or presentations. Reflective Thinking: Demonstrating critical reflection on learning outcomes, challenges, and practical applications.

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Introduction:

Light is one of the most fundamental phenomena in nature and plays a crucial role in how humans perceive and understand the world. Every day we encounter light interacting with different forms of matter: mirrors reflect our image, lenses refract light to focus images in cameras and glasses, surfaces absorb light and appear with different colors, and some materials emit light through fluorescence or phosphorescence. These phenomena are not only central to physics but also to modern technologies such as lasers, fiber optics, optical sensors, solar panels, and digital displays.

Understanding the interaction between light and matter allows students to explore fundamental physical concepts while developing analytical thinking and observation skills. This learning unit focuses on the main mechanisms of light-matter interaction: reflection, refraction, absorption, and emission. Through a combination of observation, experimental activities, and digital simulations, students will investigate how light behaves when it encounters different materials.

In addition to traditional hands-on laboratory activities, this unit integrates Augmented Reality (AR) technologies to enhance the learning experience. AR allows students to visualize processes that are normally invisible to the naked eye, such as the behavior of photons or the microscopic interactions between light and atoms. By manipulating virtual environments and observing real-time changes in physical phenomena, learners can develop a deeper conceptual understanding of how light behaves.

The structure of the learning unit is organized into three main phases: Explore, Execute, and Enhance. In the Explore phase, students are introduced to the key concepts through observation and guided discussion. In the Execute phase, they apply these concepts through structured experiments and collaborative activities. In the Enhance phase, AR tools are used to extend and deepen understanding by allowing immersive visualization and interactive exploration of physical phenomena.

The integration of experimental activities and AR-based simulations promotes inquiry-based learning, encourages collaboration among students, and fosters critical thinking. By connecting theoretical knowledge with practical observation and digital exploration, this learning unit aims to create a comprehensive and engaging learning experience.

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Ultimately, students will gain a deeper understanding of how light interacts with matter and how these interactions are applied in everyday technologies and natural phenomena.

Section 1: Explore

Engagement videos:

https://www.youtube.com/watch?v=BUYeQa_-ojk

https://www.youtube.com/watch?v=3-V-uRXDiJk

https://www.youtube.com/watch?v=DOsro2kGjGc

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Observation and Conceptual Understanding

The Explore phase introduces students to the fundamental ideas of light and matter through observation, curiosity-driven inquiry, and guided discussion. The aim of this stage is to create a conceptual foundation before moving into more structured experimentation.

Light is an electromagnetic wave that can travel through empty space and different materials. Light and matter interact primarily through four fundamental processes: absorption, reflection, transmission, and emission. These interactions depend on the chemical structure and physical properties of the material encountered by the electromagnetic radiation and the wavelength of the light.

Core Interaction Mechanisms

Reflection occurs when light bounces off a surface. This phenomenon is responsible for the images seen in mirrors and many reflective surfaces. The law of reflection states that the angle of incidence (the angle between the incoming light and the normal to the surface) is equal to the angle of reflection.

Transmission: Light passes through a medium. Refraction occurs when light passes from one medium into another and changes direction. This happens because the speed of light changes when traveling through materials with different optical densities. A common example of refraction can be observed when a straw placed in a glass of water appears bent.

Absorption occurs when a material takes in light energy and converts it into other forms of energy, such as heat. The colors we see in objects are closely related to absorption: materials absorb certain wavelengths of light and reflect others.

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Emission occurs when atoms or molecules release energy in the form of light. This can occur in phenomena such as fluorescence, phosphorescence, and the light produced by LEDs.

Scattering: Light is redirected in multiple directions when it hits small particles or uneven surfaces.

Understanding these interactions requires students to observe real-world examples and connect them with physical explanations. During the Explore phase, teachers encourage students to actively observe and identify these phenomena in everyday situations.

Exploration Activities

1. Visual Introduction

The teacher introduces the topic by showing images or short videos demonstrating different examples of light interacting with matter. Examples may include:

- Light reflecting in mirrors
- Light passing through prisms and forming rainbows
- Shadows formed by opaque objects
- Fluorescent materials glowing under ultraviolet light

Students are asked to describe what they observe and identify differences between materials.

2. Brainstorming Activity

Students work in small groups and create a list of situations in everyday life where light interacts with matter. Examples may include:

- Reflection in water

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- Light passing through windows
- Colors observed in objects
- Light emitted by screens or lamps

Each group shares its observations with the class.

3. Simple Observation Experiments

Students perform quick exploratory experiments using simple materials:

- Flashlights
- Transparent plastic sheets
- Mirrors
- Colored paper
- Glass containers filled with water

Students observe how light behaves when interacting with different surfaces and record their observations.

Expected Learning Outcomes

By the end of the Explore phase students should:

- Recognize common examples of light-matter interactions
- Develop observational skills
- Formulate questions about how and why these phenomena occur

Students should also generate hypotheses that will be tested during the experimental phase.

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Section 2: Execute

Hands-on Experimentation and Practical Investigation

In the Execute phase students apply the concepts introduced in the Explore phase through structured experimental activities. The objective is to develop practical scientific skills such as measurement, observation, data analysis, and teamwork.
Experiments allow students to verify the physical laws governing light and to understand how different materials influence light behavior.

Experiment 1: Reflection
Students investigate the law of reflection using mirrors and a light source.
Materials

- Plane mirror
- Laser pointer or flashlight
- Protractor
- Paper and pencil

Procedure
Students direct a light beam toward the mirror and measure the angles of incidence and reflection using a protractor.
Observation
Students verify that the angle of incidence equals the angle of reflection.

Experiment 2: Refraction
Students explore how light bends when passing through different materials.
Materials

- Transparent container filled with water
- Pencil or straw
- Laser pointer or flashlight

Procedure
Students shine light through the container and observe how the direction of the beam changes.
Observation
Students observe that light bends when entering and leaving the water.

Experiment 3: Absorption
Students investigate how different materials absorb light.

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Materials
- Colored paper
- Thermometer
- Light source

Procedure
Students expose different colored surfaces to light and measure temperature changes.

Observation
Darker colors typically absorb more light energy and become warmer.

Data Analysis
Students record observations in tables and compare results with other groups.
They discuss questions such as:
- Why do some materials reflect more light than others?
- Why does light bend when passing through water or glass?
- How does color affect absorption?

Students prepare a short group report summarizing their results and interpretations.

Role of Augmented Reality in the Execute Phase

AR technology can support the experimental phase by allowing students to simulate experiments or visualize underlying processes. AR tools can display the path of photons, show how light waves propagate, or illustrate atomic-level interactions.
For example, students can observe virtual representations of photons interacting with materials, making it easier to understand processes that cannot be seen directly.

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Section 3: Enhance

Augmented Reality for Deeper Understanding

The Enhance phase integrates Augmented Reality technologies to expand students' understanding beyond what can be observed through traditional experiments.
AR tools allow students to explore virtual environments where light and matter interactions are visualized dynamically and interactively.

How AR Improves Learning
Augmented Reality provides several educational advantages:

1. *Visualization of Invisible Phenomena*
Many physical processes occur at scales that cannot be observed directly. AR can represent photons, electromagnetic waves, and atomic interactions.

2. *Interactive Learning*
Students can manipulate variables such as wavelength, angle of incidence, and material properties.

3. *Enhanced Engagement*
AR environments stimulate curiosity and motivate students to explore scientific concepts actively.

4. *Conceptual Understanding*
Complex concepts such as wave propagation or photon absorption become easier to understand when visualized dynamically.

AR Exercise: Light and Matter - How They Interact

This learning unit is complemented by the AR exercise "Light and Matter: How They Interact" developed in Delightex Studio for the BioS4You 2.0 project. Through six interactive scenes, students experience the fundamental principles of geometric optics and wave theory in an immersive augmented reality environment.
Scene 1: Introduction displays the title and a three-panel overview showing the three main concepts: Reflection (mirror with symmetrical

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angles), Refraction (light bending through a prism with Snell's Law), and Electromagnetic Waves (perpendicular electric and magnetic fields).

Scene 2: Light Rays & Angles introduces the fundamental convention in optics: measuring angles from the normal rather than from the surface. Students observe a light ray hitting a surface, with a dashed normal line perpendicular to the surface and the incident angle θ_i clearly marked between the ray and the normal.
This foundational concept prepares students for understanding both reflection and refraction, where all angle measurements reference the normal line.

Scene 3: Reflection - Law of Equal Angles demonstrates the Law of Reflection. Students see an incident ray, a mirror surface, and a reflected ray with the formula $\theta_i = \theta_r$ prominently displayed. The symmetry of reflection becomes visually obvious as both angles are measured from the same normal line. A quiz challenges students to apply this law: if light hits a mirror at 30° from the normal, at what angle does it reflect?
By visualizing the perfect symmetry of reflection, students understand why mirrors produce accurate images and why the normal serves as the reference line.

Scene 4: Refraction - Snell's Law shows light passing from air ($n_1 = 1.0$) into glass ($n_2 = 1.5$). Students observe the incident ray bending toward the normal as it enters the denser material, with angles θ_1 and θ_2 clearly marked. Snell's Law formula $n_1\sin(\theta_1) = n_2\sin(\theta_2)$ is displayed, connecting the mathematical relationship to the visual phenomenon. A quiz asks students to predict what happens when light enters glass from air.
This scene bridges the gap between the abstract formula and the observable bending of light, explaining phenomena like the bent appearance of objects in water.

Scene 5: Electromagnetic Waves presents a 3D visualization of light as an electromagnetic wave. Students observe the electric field E oscillating vertically, the magnetic field B oscillating horizontally perpendicular to E, and both perpendicular to the propagation direction v. The wavelength λ is clearly marked. A quiz addresses the perpendicular relationship between E, B, and v.
By visualizing the invisible electromagnetic nature of light, students understand that light is not just a ray but a wave with oscillating electric and magnetic components.

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Scene 6: Final Assessment consolidates learning through three comprehensive quizzes covering refraction phenomena (bent straw in water), Snell's Law calculations, and wavelength determining light color. Successfully completing all quizzes unlocks the congratulations message, providing closure and a sense of achievement.
This assessment phase ensures students can apply optical principles to real-world situations and connect geometric optics with wave properties.

AR Learning Activity

Using an AR platform such as Delightex Edu, students interact with a virtual environment where photons interact with different materials.

Students can:
- Change the wavelength of light
- Modify the angle of incidence

- Switch between materials such as glass, water, or metal

They observe how these changes affect reflection, refraction, absorption, and emission.
Students capture screenshots or short videos to document their observations.

Examples of Useful AR Applications
Some AR tools that can support physics learning include:
- Delightex Edu
- Merge EDU
- Physics Toolbox AR
- JigSpace

These tools allow teachers to create immersive learning experiences that combine real-world environments with digital simulations.

Conclusion:

This learning unit has explored the fundamental interactions between light and matter through observation, experimentation, and digital simulation.
Students began by observing real-world examples of light interacting with different materials. Through discussion and exploratory activities they developed curiosity and formulated questions about the behavior of light.
The experimental phase allowed students to test their hypotheses through hands-on activities involving reflection, refraction, and

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absorption. By measuring angles, observing light paths, and recording data, students gained practical experience with scientific investigation.
The integration of Augmented Reality significantly enhanced the learning process. AR technologies allowed students to visualize microscopic processes and manipulate physical variables in ways that would not be possible in traditional laboratory settings.
By combining observation, experimentation, and immersive digital tools, students developed a deeper understanding of the physics of light and matter. They also strengthened transversal skills such as collaboration, critical thinking, and scientific communication.
The concepts explored in this unit connect directly to many real-world technologies, including optical instruments, telecommunications, digital displays, and renewable energy systems.
Encouraging students to explore these connections helps them appreciate the relevance of physics in everyday life and motivates further exploration of scientific topics.

The AR exercise "Light and Matter: How They Interact" developed for the BioS4You 2.0 project brings these concepts to life through six interactive scenes in Delightex Studio. Students progress from understanding angle measurement conventions to visualizing electromagnetic wave structure, experiencing optical phenomena that bridge geometric optics and wave theory in ways that traditional diagrams cannot convey.

Phase	Description
Explore	- Research and Discovery: Students begin by investigating examples of light-matter interaction that occur in everyday life, such as rainbows, mirrors, lenses, and screens. They are encouraged to observe phenomena around them, pose questions, and relate these observations to prior knowledge of physics. This stage fosters curiosity and encourages learners to make connections between abstract concepts and tangible experiences.
	- Content Development: Teachers provide introductory explanations on the nature of light, its properties, and how it interacts with matter. Visual materials, including diagrams, animations, and short videos, help students conceptualize reflection, refraction, absorption, and scattering, making invisible phenomena more accessible.
	- Needs Analysis: Teachers assess students' prior understanding and identify misconceptions, such as confusing reflection with refraction or misunderstanding how light travels through different media. Initial discussions and diagnostic activities ensure that the instruction is tailored to learners' knowledge levels.
Execute	- Curriculum Implementation: Students engage in structured laboratory activities that demonstrate reflection, refraction, absorption, and scattering. They perform experiments using prisms, lenses, mirrors, and light sources, collecting data and making detailed

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	observations. These hands-on experiences allow students to link theory to practice, observing how light behaves in controlled settings.
	- Interactive Exercises: Working in groups, learners conduct collaborative experiments and analyze results. They discuss patterns in data, compare findings, and solve practical problems, such as predicting light paths through different materials. This collaborative approach promotes communication skills, critical thinking, and teamwork.
	- Feedback Collection: Students share their experimental results with peers and teachers, reflect on discrepancies, and discuss explanations. Teachers provide guidance to help learners refine their understanding and consolidate key concepts. Peer feedback encourages active engagement and reinforces learning.
Enhance	- AR Integration: Students use Augmented Reality (AR) platforms to visualize photon behavior, light paths, and optical phenomena in three dimensions. AR allows them to explore reflection, refraction, diffraction, and absorption interactively, offering a dynamic perspective that complements hands-on experiments.
	- Interactive Learning: Learners manipulate variables such as light angle, medium type, and wavelength in real time, observing the immediate effects on light behavior. This interactivity deepens comprehension and encourages experimentation in a safe and engaging digital environment.

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