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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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Introduction

This document describes the Augmented Reality (AR) exercise titled Light and Matter: How They Interact, designed for students aged 17–19 within the European project BioS4You 2.0 (Work Package 3: AR Exercises).

The aim of this exercise is to help students understand how light interacts with matter through reflection, refraction, and electromagnetic wave propagation, connecting physics (optics, wave theory, geometric optics), mathematics (angle measurement, trigonometry, Snell's Law), and engineering applications (lenses, optical fibers, optical instruments).

This document follows the standard BioS4You AR Exercise template and is organized into the following sections:

General Information: title, authors, target group, duration, keywords, and topics Pedagogical Specifications: learning objectives, methodology, integration with curriculum Technical Specifications: hardware, software, AR experience design

The exercise has been developed using the 3E approach (Explore – Execute – Enhance), encouraging students to explore light-matter interactions step-by-step through interactive AR scenes showing the law of reflection, Snell's Law of refraction, and electromagnetic wave properties.

	General Information
Name of the exercise:	**Light and Matter: How They Interact** From reflection to electromagnetic waves: exploring optical phenomena The title reflects both the fundamental physical principles and practical applications of optics. "Light and Matter: How They Interact" emphasizes the dual focus on geometric optics and wave theory, while the subtitle "From reflection to electromagnetic waves" highlights the journey from macroscopic optical phenomena (reflection in mirrors, refraction through materials) to microscopic wave properties (electric and magnetic field oscillations) through Snell's Law and electromagnetic wave theory.
Description of the exercises:	Light and Matter: How They Interact is designed for students aged 17–19 to explore the fundamental principles of light-matter interactions and optical phenomena through Augmented Reality. The main objective is to help students understand how light behaves when it encounters different materials, how angles are measured in optics, and how electromagnetic waves propagate through space.

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	Students will: • Understand the Law of Reflection and angle measurement from the normal • Visualize Snell's Law of refraction and light bending in different media • Explore electromagnetic wave structure with perpendicular electric and magnetic fields • Learn about practical applications in optical instruments, lenses, and telecommunications The AR experience uses Delightex Studio – Spaces (Marker) with 6 sequential scenes and 6 integrated quizzes.
Participants:	The exercise is suitable for both individual students and small groups of 3–5 members. Working in groups is recommended to stimulate discussion about light-matter interactions, compare observations of reflection and refraction processes, and develop collaborative problem-solving skills when analyzing optical principles in real-world applications (mirrors, lenses, prisms, optical fibers).
Participants' age range:	Students should have basic understanding of physics and mathematics, in particular the concepts of light, electromagnetic radiation, angles, geometric optics, and basic trigonometry (sine, cosine functions). Prior knowledge of wave properties (wavelength, frequency) and coordinate systems is recommended but not mandatory.
STEM subject and specific topic:	STEM Subject: Physics, Mathematics, Engineering Specific Topic: Geometric optics, Law of Reflection, Snell's Law of refraction, refractive index, electromagnetic waves, electric and magnetic field oscillations, wave propagation, optical phenomena Main challenge of the topic: Students often struggle to understand why angles are measured from the normal rather than from the surface, how Snell's Law explains light bending when entering different materials, and how electric and magnetic fields can oscillate perpendicular to each other and to the propagation direction. AR visualization helps bridge these abstract optical concepts with tangible real-world applications in mirrors, lenses, and optical instruments.

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Gamification process:	The gamification strategy follows BioS4YOU WP2 guidelines, focusing on challenge-based learning and immediate feedback with Delightex Studio. Challenge-based learning: Students follow the journey from light rays and angle measurement to electromagnetic wave propagation. Each scene presents a quiz that must be answered correctly to proceed to the next stage, creating a progressive learning pathway. Immediate feedback: Delightex provides instant visual feedback when students answer quiz questions. Correct answers unlock the NEXT button and advance the storyline, while incorrect answers prompt students to reconsider the optical and wave principles involved. Achievement unlocking: Scene 6 requires completing all three optical phenomena quizzes to receive the final congratulations message, providing a sense of accomplishment and mastery.
Written or graphic description of Augmented info:	The AR experience is developed in Delightex Studio – Spaces (Marker) and includes: Scene 1: Title and introduction Title "Light and Matter: How They Interact" with START button Three-panel diagram showing Reflection (mirror with equal angles), Refraction (light bending through prism), and Electromagnetic Wave (E and B fields perpendicular) Scene 2: Light Rays & Angles Diagram showing light source, incident ray, surface, normal (perpendicular to surface), and incident angle θ_i measured from the normal Scene 3: Reflection - Law of Equal Angles Diagram showing incident ray, normal, reflected ray, and mirror surface with $\theta_i = \theta_r$ formula Quiz: According to the Law of Reflection, if light hits a mirror at 30° from the normal, at what angle does it reflect? Scene 4: Refraction - Snell's Law Diagram showing light passing from air ($n_1 = 1.0$) to glass ($n_2 = 1.5$), with incident angle θ_1 and refracted angle θ_2, demonstrating Snell's Law: $n_1\sin(\theta_1) = n_2\sin(\theta_2)$ Quiz: What happens to a light ray when it enters glass from air? Scene 5: Electromagnetic Waves 3D diagram showing electric field E (vertical oscillation), magnetic field B (horizontal oscillation), wavelength λ, and direction of propagation v, with all three mutually perpendicular Quiz: In an electromagnetic

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	wave, how are the electric and magnetic fields oriented? Scene 6: Final Assessment Three quizzes on: • Refraction phenomenon (bent straw in water) • Snell's Law calculation formula • Wavelength determining light color Final congratulations message after completing all quizzes.
External (or extra) tools required	• Devices: Smartphones or tablets with Delightex app installed (iOS or Android) • AR markers: Required; Delightex Studio – Spaces (Marker) uses marker-based AR. Students scan the provided marker to launch the AR experience • Printed worksheets: Optional for note-taking during AR exploration • Internet connection: Required for initial app download and AR content loading
Links (video, images, text online and so on).	**QUIZ** The quizzes are integrated natively in Delightex Studio (scenes 2-5) and do not require external links. Students answer directly within the AR experience with automatic feedback.

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Pedagogical specifications

Here we will collect information on how to use the exercise in the learning session and the results and benefits of using it, from a pedagogical perspective.

How can this augmented information be used to address a STEAM topic in a more interesting way for students?

The AR exercise transforms abstract optical concepts into visual, interactive experiences that students can explore in real time. By visualizing light rays reflecting symmetrically from surfaces, witnessing light bending when entering different materials following Snell's Law, observing electromagnetic waves with perpendicular electric and magnetic fields propagating through space, and making direct connections to real optical instruments (mirrors, lenses, prisms, optical fibers), students bridge the gap between theoretical optics and practical engineering applications. The immersive nature of AR allows learners to manipulate and observe invisible wave processes and angle relationships, making geometric and wave optics tangible and engaging while demonstrating the interdisciplinary connections between physics, mathematics, and engineering.

Which pedagogical objectives are addressed through this scenario?

The exercise addresses multiple pedagogical objectives across different learning domains. Students develop understanding of geometric optics principles, the normal as the reference line for angle measurement, and the fundamental differences between reflection (angle preservation) and refraction (angle change through Snell's Law). They learn to describe how refractive index determines light bending and identify electromagnetic wave properties with perpendicular electric and magnetic field oscillations. Through AR visualization, students connect macroscopic optical phenomena to wave theory, analyze cause-effect relationships in light-matter interactions (why light bends toward the normal in denser materials), and evaluate appropriate optical principles for different applications (mirrors, lenses, optical fibers). At the competence level, the exercise develops scientific reasoning about wave propagation and critical thinking about optical instrument design and functionality in engineering and telecommunications settings.

Which results are expected to be reached with its use?

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Students are expected to explain why angles are measured from the normal rather than from the surface, describe the Law of Reflection ($\theta_i = \theta_r$) and how it explains mirror symmetry, understand how Snell's Law ($n_1\sin(\theta_1) = n_2\sin(\theta_2)$) describes light bending when entering materials with different refractive indices, and recognize that electromagnetic waves consist of perpendicular electric and magnetic fields oscillating perpendicular to the propagation direction. Assessment of these learning outcomes includes successful completion of all six quizzes during the AR experience, demonstrated ability to draw and label reflection and refraction diagrams with proper angle notation, correct explanation of why light bends toward the normal in denser materials, and appropriate application of optical principles to real-world scenarios (mirrors, lenses, optical fibers, prisms).

Which benefits are expected to be reached with its use?

The exercise provides enhanced visualization of optical and wave phenomena that cannot be directly observed with the naked eye, increasing student engagement through interactive AR technology while delivering immediate feedback that supports self-paced learning. Gamification elements maintain motivation throughout the experience. From an interdisciplinary perspective, the exercise integrates physics (geometric optics, wave theory), mathematics (angle measurement, trigonometry, Snell's Law calculations), and engineering (optical instruments, telecommunications), providing real-world context that demonstrates STEM relevance in technology and bridges theoretical optics with practical applications. Long-term benefits include establishing a foundation for advanced studies in photonics, optical engineering, telecommunications, or materials science, developing understanding of optical principles in various professional contexts (lens design, fiber optics, imaging systems), and fostering critical thinking about optical instrument design and light manipulation based on physical properties.

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Technical specifications

In this part it is necessary to specify whether the exercise was designed to be implemented with AR technology. This part is fundamental for the translation process. Please include text, audio text and all the necessary materials.

AR INFORMATION

Technology	https://edu.delightex.com/QLR-QNJ QLR QNJ Delightex Studio – Spaces (Marker) The exercise is designed to be implemented entirely with Augmented Reality. It uses marker-based AR, since Delightex Studio – Spaces (Marker) requires students to scan a printed marker to launch the AR experience and view the light-matter interaction scenes (reflection, refraction, electromagnetic waves) on their device screen.
If it's needed a marker, description of the marker	A specific marker is required for Delightex Studio – Spaces (Marker). The marker is a printed image or pattern that students scan with their smartphone or tablet camera to launch the AR experience. The marker can be a custom-designed image related to optics (such as a prism, mirror symbol, light ray diagram, or electromagnetic wave) or a standard QR-style pattern provided by Delightex.

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Hardware and software needed:	- Hardware: Smartphones or tablets with camera and internet connection. Gyroscope and accelerometer are required (standard in most modern devices) - Software: Delightex app (free, available on Android and iOS). Teachers need a Delightex educational account to access and share the AR project - Other: Printed marker for each student or group
Type of Augmented data	The AR experience integrates different types of content: • 3D text (title "Light and Matter: How They Interact", scene labels, quiz questions) • Images (three-panel introduction showing reflection/refraction/electromagnetic waves, light ray and normal diagram, Law of Reflection diagram, Snell's Law refraction diagram, electromagnetic wave 3D visualization) • Interactive buttons (START, NEXT, QUIZ buttons) • Text overlays (explanatory messages about angle measurement from the normal, reflection symmetry, Snell's Law, perpendicular electric and magnetic fields) • Quiz interface (multiple-choice questions with automatic feedback)
Written description of the AR data	When students open the exercise with Delightex app and scan the marker, they begin with Scene 1 displaying the title "Light and Matter: How They Interact" as 3D text. Below the title, a three-panel diagram shows the main concepts: Reflection (mirror with incident and reflected rays at equal angles), Refraction (light bending through a prism with Snell's Law formula), and Electromagnetic Wave (electric field E and magnetic field B oscillating perpendicular to propagation direction v). Tapping START leads to Scene 2. Scene 2 shows how to measure angles in optics. Students see a light source emitting an incident ray (yellow arrow) that hits a horizontal surface. At the impact point, a dashed blue line (the normal) extends perpendicular to the surface. The incident angle θ_i is marked between the incoming ray and the normal. Students observe that all optical angles are measured from the normal, not from the surface. NEXT button advances without

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quiz.

Scene 3 displays the Law of Reflection with a mirror surface. An incident ray arrives from the upper left, a normal (dashed blue line) stands perpendicular at the impact point, and a reflected ray bounces symmetrically toward the upper right. Both angles θ_i and θ_r are marked, and the formula $\theta_i = \theta_r$ appears prominently. A quiz asks: if light hits a mirror at 30° from the normal, at what angle does it reflect?

Scene 4 shows Snell's Law of refraction. The scene is divided horizontally: light blue air ($n_1 = 1.0$) above, darker blue glass ($n_2 = 1.5$) below. An incident ray travels through air and hits the boundary, where a vertical dashed normal line is drawn. The refracted ray continues into the glass, bending toward the normal (smaller angle θ_2). The angles θ_1 (larger, in air) and θ_2 (smaller, in glass) are marked, with the formula $n_1\sin(\theta_1) = n_2\sin(\theta_2)$ displayed. Quiz asks what happens when light enters glass from air.

Scene 5 presents electromagnetic wave structure in 3D. Students see a sinusoidal wave propagating horizontally. Red/orange arrows show the electric field E oscillating vertically (up-down), blue arrows show the magnetic field B oscillating horizontally perpendicular to E, and a black arrow indicates the direction of propagation v. The wavelength λ is marked between two wave peaks. All three vectors (E, B, v) are clearly perpendicular to each other. Quiz addresses how electric and magnetic fields are oriented in electromagnetic waves.

Scene 6 presents three consecutive quizzes about optical phenomena: which phenomenon explains why a straw appears bent in water (refraction), which equation correctly calculates the refraction angle using Snell's Law, and what determines the color of visible light (wavelength). Completing all three reveals the congratulations message.

If Image

If the AR data are Images, the formats needed are .jpg and .png (better size < 2Mb). The exercise uses multiple images:

- Scene 1: Three-panel introduction diagram showing Reflection (mirror with equal incident and reflected angles), Refraction (light bending through prism with Snell's Law formula $n_1\sin(\theta_1) = n_2\sin(\theta_2)$), and Electromagnetic Wave (electric field E and magnetic field

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	B perpendicular to propagation direction v) • Scene 2: Light rays and angles diagram showing light source, yellow incident ray, horizontal gray surface, dashed blue normal line perpendicular to surface, and incident angle θ_i marked between ray and normal • Scene 3: Law of Reflection diagram showing mirror surface, incident ray, reflected ray, normal, and equal angles $\theta_i = \theta_r$ with formula displayed prominently • Scene 4: Snell's Law refraction diagram showing two-layer system (light blue air n_1=1.0 above, dark blue glass n_2=1.5 below), incident ray in air, refracted ray bending toward normal in glass, angles θ_1 and θ_2 marked, with Snell's Law formula $n_1\sin(\theta_1) = n_2\sin(\theta_2)$ • Scene 5: Electromagnetic wave 3D diagram showing sinusoidal wave with electric field E (red/orange, vertical oscillation), magnetic field B (blue, horizontal oscillation), wavelength λ marked, and propagation direction v, demonstrating perpendicular relationship E ⊥ B ⊥ v
If Text	Short explanatory messages are displayed as text overlays inside Delightex Studio. Scene 1: Title and subtitle Scene 2: "When light hits a surface, we measure angles from the normal - a line perpendicular to the surface. The incident angle θ_i is measured between the incoming light ray and the normal. This convention makes it easier to describe reflection and refraction" Scene 3: "The Law of Reflection states that the angle of incidence equals the angle of reflection. Both angles are measured from the normal to the surface. This is why mirrors reflect light symmetrically - whatever angle light comes in at, it bounces back at the same angle on the opposite side of the normal" Scene 4: "Refraction occurs when light passes from one material to another with different optical density. Snell's Law describes how the angle changes: $n_1\sin(\theta_1) = n_2\sin(\theta_2)$, where n is the refractive index. Light bends toward the normal when entering denser materials (like glass or water) because it slows down" Scene 5: "Light is an electromagnetic wave: electric and magnetic fields oscillate perpendicular to each other and to the

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	direction of propagation. The wavelength λ determines the color of visible light (red has longer wavelengths, violet has shorter wavelengths). The wave equation describes this oscillation: $E = E_0 \sin(kx - \omega t)$" Quiz questions: • According to the Law of Reflection, if light hits a mirror at 30° from the normal, at what angle does it reflect? • What happens to a light ray when it enters glass from air? • In an electromagnetic wave, how are the electric and magnetic fields oriented? • Which phenomenon explains why a straw appears bent in a glass of water? • If $n_1 = 1.0$ (air) and $n_2 = 1.5$ (glass), and $\theta_1 = 30°$, which equation correctly calculates θ_2? • What determines the color of visible light? Final message: "Congratulations! You've successfully completed the Light-Matter Interaction exploration! You now understand reflection, refraction through Snell's Law, and electromagnetic wave properties."
If video	-
If audio	-
If 3D model	3D models in Delightex Studio can be used in formats compatible with the platform (.glb, .obj). The exercise primarily uses 3D text elements for titles and labels. Optional enhancement could include importing 3D models of laser devices or medical equipment from libraries compatible with Delightex.

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