General- Physics-2 Q4 Week-2

Fundamental Physics II (University of the Philippines System)

DEPARTMENT OF EDUCATION
SCHOOLS DIVISION OF NEGROS ORIENTAL
REGION VII
Kagawasan Ave., Daro, Dumaguete City, Negros Oriental

COMMON PROPERTIES OF LIGHT
(Maxwell's Equation and Law of Reflection)

for GENERAL PHYSICS 2/ Grade 12
Quarter 4/ Week 2

SELF-LEARNING KIT

NegOr_Q4_GenPhysics2_SLKWeek2_v2

FOREWORD

This Self-Learning Kit is designed to cater your needs as STEM students for Modular Distance Learning. It is carefully planned to holistically develop your life-long learning skills. This serves as your guide to understand the essence and importance of Maxwell's equations. This will also help you relate the properties of EM wave to the properties of vacuum and optical medium.

Moreover, included in this kit is a hands-on experiment for you to practice your scientific skills. Good luck and enjoy learning.

OBJECTIVES

At the end of this SLK, you should be able to:

K: explain the essence and implications of Maxwell's equations;

: define terms pertinent to the substantial understanding of the law of reflection;

S: perform simple ray optics and reflection experiment; and

A: apply the law of reflection in a given scenario.

LEARNING COMPETENCIES

Relate the properties of EM wave (wavelength, frequency, speed) and the properties of vacuum and optical medium (permittivity, permeability, and index of refraction) **(STEM_GP12OPTIVb-12).**

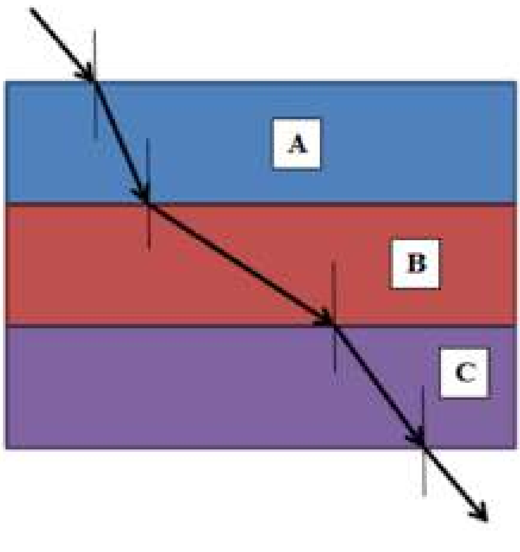
Explain the conditions for total internal reflection **(STEM_GP12OPTIVb-14).**

I. WHAT HAPPENED

PRE-TEST:

A. ***Directions:*** Choose the best word/s that correctly complete/s the statement. Be guided by the illustration on the right. Write your answers on your notebook/Answer Sheet.

1. Light travels (fastest, slowest) in media with a less optical density.
2. Light travels (fastest, slowest) in media with a lower index of refraction value.
3. When light passes into a medium in which it travels slower, the light will refract (away from, toward) the normal.
4. When light passes into a medium that is less optically dense, the light will refract (away from, toward) the normal.



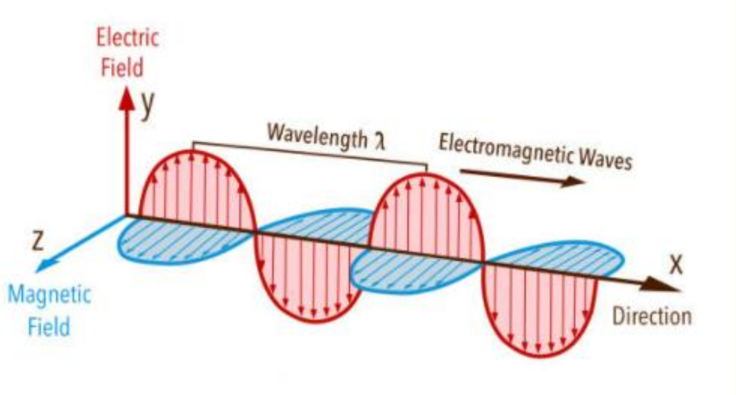
B. ***Directions:*** Based on the given illustration on the previous page, provide what is asked. Write your answer on your notebook/Answer Sheet.

- A ray of light is shown passing through three consecutive layered materials. Observe the direction of bending at each boundary and rank the three materials (A, B and C) in order of increasing index of refraction.

II. WHAT I NEED TO KNOW DISCUSSION

Maxwell's Equations

James Clerk Maxwell described ***light*** as a propagating wave made up of electric and magnetic fields. His work revealed that electromagnetic radiation came from oscillating electric and magnetic fields travelling as waves with a speed equal to the speed of light. The mathematical formula he provided yields the values of electric and magnetic fields at all points in space, using one's knowledge of the sources of these fields. Recall that a changing magnetic field indirectly yields an electric field. Similarly, a moving electric field yields a magnetic field. The interaction between the magnetic field and the electric field produces the ***electromagnetic field*** or EM field. This electromagnetic field has been associated with electromagnetic (EM) waves, in which light is a component.



Adapted from https://www.istockphoto.com/vector/electromagnetic-wave-structure-and-parameters-vector-illustration-diagram-with-gm1194626452-340233881

Figure 1. An illustration of an electromagnetic wave

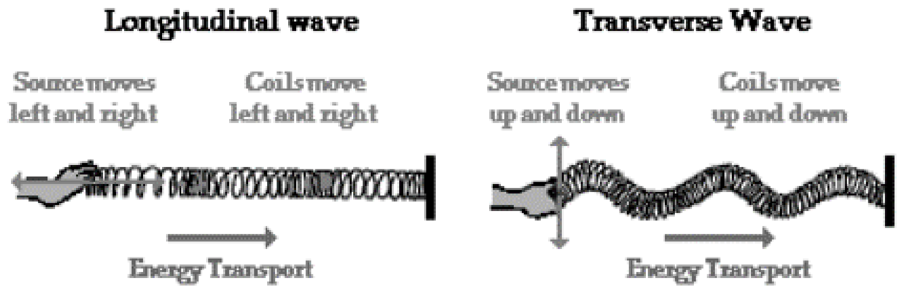
EM waves describe propagating oscillations with respect to electric and magnetic fields. Maxwell's wave equation shows that the speeds of the waves depend on the combination of constants involved in electrostatics and magnetism. His calculations led him assert that light must be an EM disturbance (in the form of waves) propagating through the EM field in accordance with EM laws.

Light as an Electromagnetic Wave

An **electromagnetic wave** is understood to be a transverse wave produced by a vibrating electric charge. Being a wave, an EM wave possesses the characteristics of wavelength, frequency, and speed. The wavelength is the measurement of the distance between the successive crests (highest points) or troughs (lowest points) of a wave. The frequency is the number of waves that propagate in a unit of time, which is usually in seconds. The speed is how fast the wave is propagating. Based on the wave equation, you have

$$v = f\lambda$$

In this equation, v is the speed of the wave, f is the frequency, and λ is its wavelength.



Adapted from https://www.physicsclassroom.com/class/waves/Lesson-1/Categories-of-Waves

Figure 2. Two kinds of waves: longitudinal and transverse

Recall that a wave can be either a transverse wave or a longitudinal wave. A ***transverse wave*** is a wave in which the movement of the energy is perpendicular to the movement of the particle of the wave, whereas a ***longitudinal wave*** is a wave with the energy moving parallel to the movement of the particle of the wave.

Electromagnetic waves are transverse waves that have the capability of propagating even without any medium. This means an EM wave can travel though a vacuum, unlike a sound wave that needs the molecules of a medium to propagate from one point to another. As EM wave enter any medium, various properties of the medium dictate how EM waves will propagate. The most common of these properties is the index of refraction, which you will encounter on the next module. The other two properties are electric permittivity and magnetic permeability. ***Electric permittivity*** is related to the energy stored in an electric field, whereas ***magnetic permeability*** is similar to the energy stored in a magnetic field. Their collective effect to light (being an EM wave) is given by the equation

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

In this equation, c is the speed of light, μ_0 is the magnetic permeability, and ε_0 is the electric permittivity. From this equation, you can infer that the magnetic permeability and electric permittivity are inversely proportional to the speed of light. In other words, as either the magnetic permeability or the electric permittivity increases, the speed of light decreases. Conversely, a decrease in the values of the constant quantities considers a higher value for the speed of light.

Reflection of Light

When light strikes a material, it has the capacity to bounce against it or be reflected. This phenomenon is known as the **reflection of light**, and it is governed by the **law of reflection**, which is stated as:

"The angle if incidence (θ_i) is equal to the angle of reflection (θ_r). Furthermore, the incident ray, the reflected ray, and the normal to the surface all lie on the same plane".

In Figure 3 below, the reflecting surface corresponds to any surface where a light ray can bounce against. Mirrors are most commonly used to represent such reflecting surfaces. The **incident ray** is the light ray that approaches the reflecting surface and forms an angle with the line that is *normal* or perpendicular to the surface. This formed angle is referred to as the **angle of incidence** (θ_i). The light ray that bounces off the reflecting surface is the **reflected ray**. This ray also forms an angle with the *normal line*, and this angle is referred to as the **angle of reflection** (θ_r).

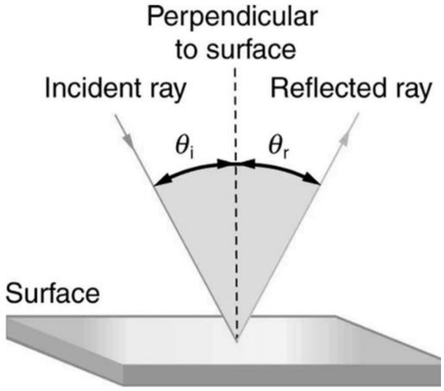


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Figure 3. The Law of Reflection

When light is incident on a smooth surface, it produces **regular reflection**. In regular reflection, the reflected rays have only one direction. Meanwhile, **diffused reflection** is produced from light being incident to rough surfaces wherein the reflected rays have varying directions (See Figure 4). To illustrate, you are able to read because of the diffused reflection of light from this page. This kind of reflection enables you to see objects from any direction or position (See Figure 5).

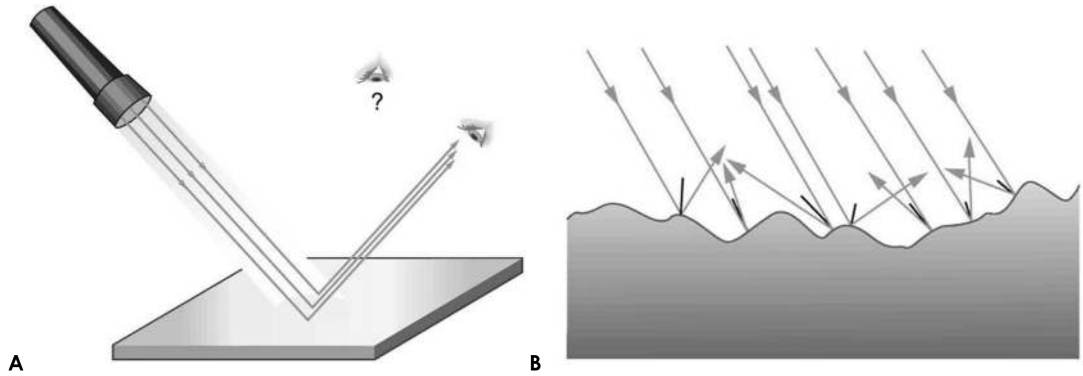

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Figure 4. (a) Regular reflection; (b) diffused reflection

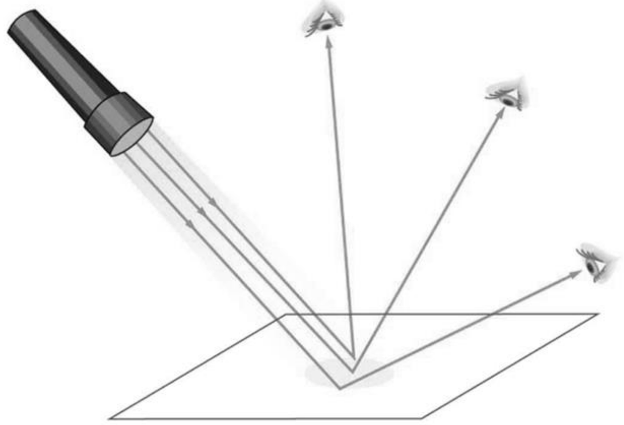

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Figure 5. When a sheet of paper is illuminated with many parallel incident rays, it can be seen at many different angles, because its surface is rough and diffuses the light

Total Internal Reflection

Consider sighting the long side of an isosceles triangle at a pin or other object held behind the opposite face. When done so, an unusual observation - a discrepant event - is observed. Figure 6 below depicts the physical situation. A ray of light entered the face of the triangular block at a right angle to the boundary. This ray of light passes across the boundary without refraction since it was incident along the normal. The ray of light then travels in a straight line through the glass until it reaches the second boundary. Now instead of transmitting across this boundary, all of the light seems to reflect off the boundary and transmit out the opposite face of the isosceles triangle.

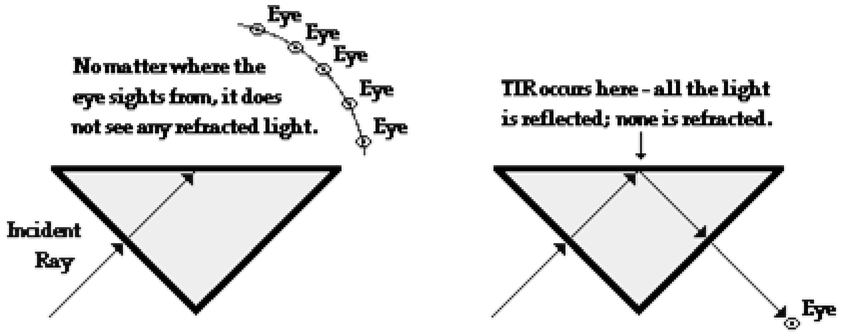

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Figure 6. The discrepant event – total internal reflection

The phenomenon observed is known as total internal reflection. ***Total internal reflection****, or* ***TIR*** as it is intimately called, is the reflection of the total amount of incident light at the boundary between two media.

To understand total internal reflection, we will begin with a thought experiment. Suppose that a laser beam is submerged in a tank of water (don't do this at home) and pointed upwards towards water-air boundary. Then suppose that the angle at which the beam is directed upwards is slowly altered, beginning with small angles of incidence and proceeding towards larger and larger angles of incidence. What would be observed in such an experiment? If we understand the principles of boundary behavior, we would expect that we would observe both reflection and refraction. And indeed, that is what is observed mostly. But that's not the only observation that we could make. We would also observe that the intensity of the reflected and refracted rays do not remain constant. At angle of incidence close to *0* degrees, most of the light energy is transmitted across the boundary and very little of it is reflected. As the angle is increased to greater and greater angles, we would begin to observe less refraction and more reflection. That is, as the angle of incidence is increased, the brightness of the refracted ray decreases and the brightness of the reflected ray increases. Finally, we would observe that the angles of the reflection and refraction are not equal. Since the light waves would refract away from the normal, the angle of refraction would be greater than the angle of incidence. And if this were the case, the angle of refraction would also be greater than the angle of reflection (since the angles of reflection and incidence are the same). As the angle of incidence is increased, the angle of refraction would eventually reach a 90-degree angle. These principles are depicted in the diagram below.

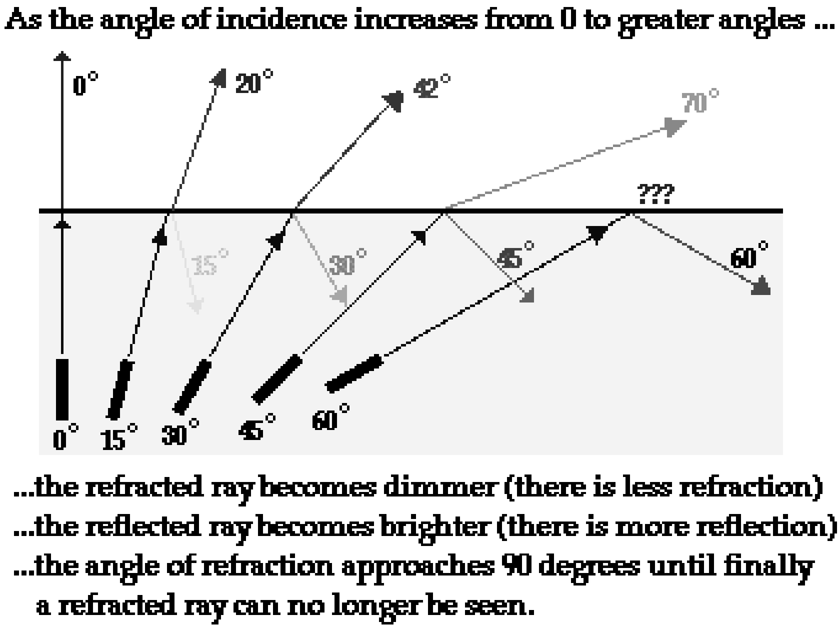

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Figure 7. Altering the angle at which the laser beam submerged in water is directed upwards

The maximum possible angle of refraction is 90-degrees. If you think about it, you recognize that if the angle of refraction were greater than 90 degrees, then the refracted ray would lie on the incident side of the medium - that's just not possible. So, in the case of the laser beam in the water, there is some specific value for the angle of incidence (we'll call it the *critical angle*) that yields an angle of refraction of 90-degrees. This particular value for the angle of incidence could be calculated using Snell's Law ($n_i = 1.33$, $n_r = 1.000$, $\theta_r = 90$ *degrees*, $\theta_i = ?$) and would be found to be 48.6 degrees. Any angle of incidence that is greater than 48.6 degrees would not result in refraction. Instead, when the angles of incidence is greater than 48.6 degrees (the critical angle), all of the energy (the ***total*** energy) carried by the incident wave to the boundary stays within the water (***internal*** to the original medium) and undergoes ***reflection*** off the boundary. When this happens, ***total internal reflection*** occurs.

Two Conditions for Total Internal Reflection

Total internal reflection (TIR) is the phenomenon that involves the reflection of all the incident light off the boundary. TIR only takes place when both of the following two conditions are met:

1. The light is in the denser medium and approaching the less dense medium.
2. The angle of incidence is greater than the so-called critical angle.

Total internal reflection will not take place unless the incident light is traveling within the more *optically dense* medium towards the *less optically dense* medium. TIR will happen for light traveling from water towards air, but it will not happen for light traveling from air towards water. TIR would happen for light traveling from water towards air, but it will not happen for light traveling from water *(n=1.333)* towards crown glass *(n=1.52).* TIR occurs because the angle of refraction reaches a 90-degree angle before the angle of incidence reaches a 90-degree angle. The only way for the angle of refraction to be greater than the angle of incidence is *for light to bend away from the normal.* Since light only bends away from the normal when passing from a denser medium into a less dense medium, then this would be a necessary condition for total internal reflection.

Total internal reflection only occurs with large angles of incidence - larger than the critical angle. As mentioned above, the critical angle for the water-air boundary is 48.6 degrees. So, for angles of incidence greater than 48.6-degrees, TIR occurs. But 48.6 degrees is the critical angle only for the water-air boundary. The actual value of the critical angle is dependent upon the two materials on either side of the boundary. For the crown glass-air boundary, the critical angle is 41.1 degrees. For the diamond-air boundary, the critical angle is 24.4 degrees. For the diamond-water boundary, the critical angle is 33.4 degrees. The critical angle is *different* for *different media.*

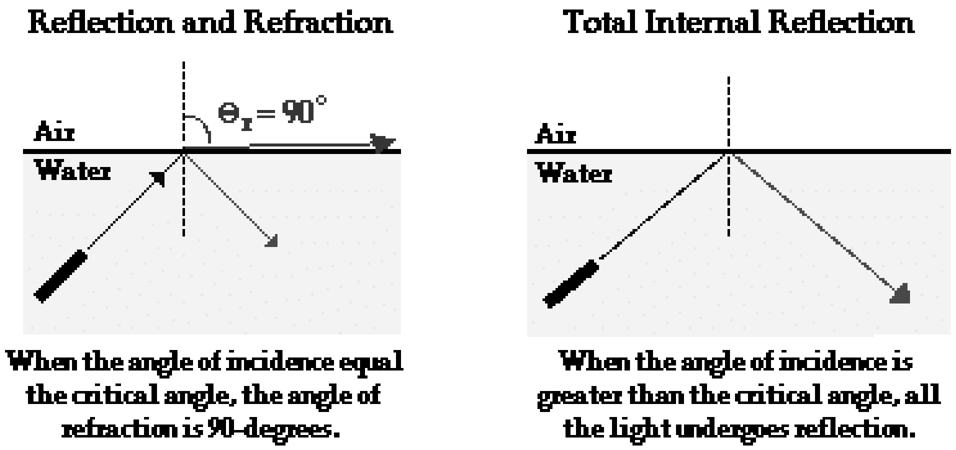

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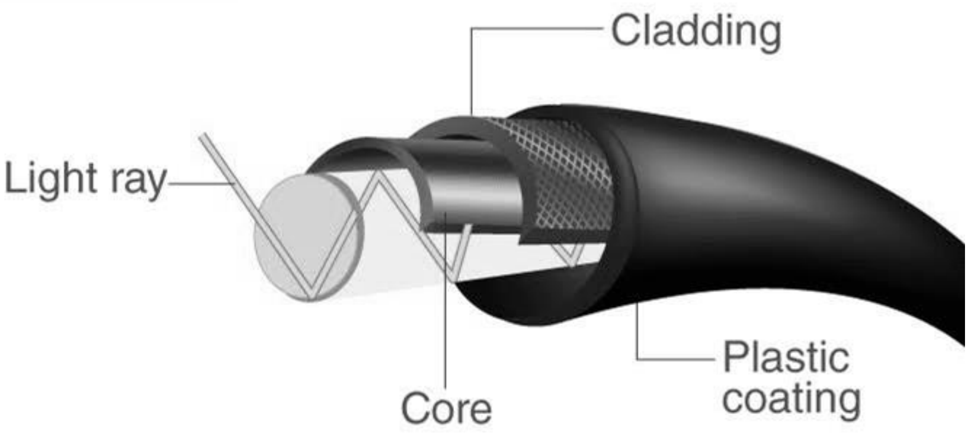
Figure 8. A comparison between refraction and reflection

One application of total internal reflection is in the operation of optical fibers. In an optical fiber, light remains confined within the core of simple optical fiber because of total internal reflection from core cladding boundary. If light hits the boundary of a material of lower refractive index at a steep enough angle, it cannot get out and it is reflected back into the high index medium.

An optical fiber is a thin rod of high-quality glass (See Figure 9). Very little is absorbed by the glass. Optical fibers can carry more information than an ordinary cable of the same thickness. The signals in optical fibers do not weaken as much over long distances as the signals in ordinary cables.

Optical fibers are found in decorative lamps, glass fibers (used for communication technologies), and endoscopes (used to view human body's internal organs.



Retrieved from https://byjus.com/physics/what-is-optical-fiber/

Figure 9. An optical fiber

Performance Task:

Hands-on Experiment on Reflection

Directions: Perform the experiment below. After which, answer the guide questions that follow.

Objective: Perform a simple ray optics and reflection experiment.

Materials:

- Bond paper
- Pen
- Ruler
- Protractor
- Mirror
- Push pin
- Graphing paper

Procedure:

a. Prepare the experimental set-up. In a sheet of bond paper, use a dark pen to draw a straight horizontal line and a line perpendicular to it. Designate the intersection point as *A*.

b. Arbitrarily choose a location on the left side of the perpendicular line and push a pin. Designate the position of the pin as point *B*. Draw a straight-line connecting points *A* and *B*.
c. Position the mirror center at *A* such that the mirror's surface is parallel to the horizontal line.
d. Position yourself on the right-hand side of the perpendicular line and locate point *C*. Put a pin on that location such that the line *BA* and line *AC* are perpendicular to each other.
e. Using a protractor measure the angle subtended by line *AB* to the perpendicular line. This will be called the incident angle, θ_i.
f. Using a protractor measure the angle subtended by line *AC* to the perpendicular line. This will be called the reflection angle, θ_i.
g. Repeat steps *a-f* for five (5) different locations of point *B* and their corresponding point *C*.

2. Plot each on a graphing paper. The expected result is as follows:

(never mind the numbers indicated herein)

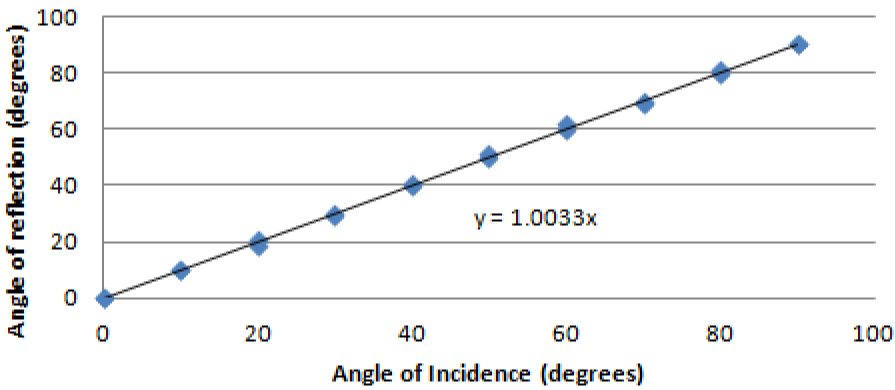


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Figure 10. The angle of incidence vs the angle of reflection

***Guide Questions*:**
1. What is the relationship between θ_r and θ_i?
2. Create a report detailing your results.

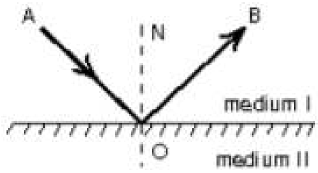
III. WHAT I HAVE LEARNED

EVALUATION/POST-TEST

Multiple Choice: Choose the letter of the correct answer. Write it in your notebook/Answer Sheet.

1. It is the measurement of the distance between the successive crests or troughs of a wave.
   a. wavelength b. frequency c. speed
2. A kind of wave where the movement of the energy is perpendicular to the movement of the particle of the wave.
   a. transverse b. longitudinal c. both a and b
3. As EM waves enters any medium, various properties of the medium dictate how EM waves will propagate. This property is related to the energy stored in an electric field.
   a. Electric permittivity c. index of refraction
   b. magnetic permeability
4. EM waves are transverse waves that have the capability of propagating even without a medium. This statement means __________.
   a. EM wave can travel through a vacuum.
   b. EM wave cannot travel through vacuum.
   c. EM wave needs the molecules of a medium to propagate from one point to another.
5. All the following are implications of Maxwell's equations except one. Which is it?
   a. It provides an important link among the concepts of electricity, magnetism and light.
   b. It explains how light behaves as it propagates.
   c. It shows that the speeds of the waves do not depend on the combination of constants involved in electrostatics and magnetism.
6. When a ray of light enters from denser medium to rare medium, it bends ______________.
   a. towards normal
   b. away from normal
   c. perpendicular to normal
7. The outer concentric shell in fiber optic is called _____________.
   a. Cladding b. core c. coat
8. The entire light is reflected into the denser medium, which is called total _____________.
   a. Internal reflection of light
   b. External reflection of light
   c. Internal refraction of light
9. The critical angle for water-air boundary is _______________ degrees.
   a. 46.8 b. 48.6 c. 46.6

10. The diagram shows total internal reflection. Which of the following statements is not true?



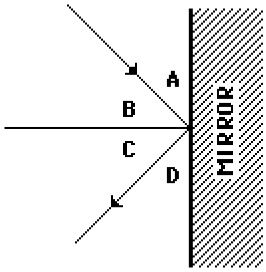
a. Angle AON is the angle of incidence.
b. Angle AON = angle BON
c. Angle AON must be the critical angle.

11. For total internal reflection to occur, two conditions must be met except _________.
a. The index of refraction must decrease across the boundary in the direction of light refraction.
b. The angle if incidence of the light ray must not exceed the critical angle of the interface.
c. The light is in the less dense medium and approaching the denser medium.

12. Which of the following phenomena takes place inside an optical fiber?
a. Reflection b. total internal reflection c. dispersion

13. Light is confined within the core of a simple optical fiber by ___________.
a. Total internal reflection at the edge of the cladding.
b. Reflection from the fiber's plastic coating.
c. Total internal reflection at the core cladding boundary.

For numbers 14-15, refer to the diagram below.



14. Which of the angles is the angle of incidence?
a. A b. B c. C

15. Which of the angles is the angle of reflection?
a. A b. B c. C

REFERENCES

Electromagnetic Waves. Retrieved from https://www.istockphoto.com/vector/electromagnetic-wave-structure-and-parameters-vector-illustration-diagram-with-gm1194626452-340233881

David, Oliver M. *General Physics 2*. Makati City, Philippines: DIWA Learning Systems Inc., 2017.

Physics Tutorial: Total Internal Reflection. Retrieved from https:/www.physicsclassroom.com/class/refrn/Lesson-3/Total-Internal-Reflection

The Law of Reflection | Physics. Retrieved from https://courses.lumenlearnng.com/physics/chapter/25-2-the-law-of-reflection/

Test: Total Internal Reflection | 10 Questions MCQ Test. Retrieved from https://edurev.in/course/quiz/attempy/-1_Test-Total-Internal-Reflection/7674cfce-a4d6-4191-810c-885f042fca08

Total Internal Reflection. Retrieved from https://www.physicsclassroom.com/class/refrn/Lesson-3/Total-Internal-Reflection

What is Optical Fiber? – Definition and Types of Optical Fiber. Retrieved from https://byjus.com/physics/what-is-optical-fiber/

DEPARTMENT OF EDUCATION
SCHOOLS DIVISION OF NEGROS ORIENTAL

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Schools Division Superintendent

JOELYZA M. ARCILLA EdD
OIC - Assistant Schools Division Superintendent

MARCELO K. PALISPIS EdD JD
OIC - Assistant Schools Division Superintendent

NILITA L. RAGAY EdD
OIC - Assistant Schools Division Superintendent/CID Chief

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Education Program Supervisor – (LRMDS)

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ROWENA R. DINOKOT
Writers

STEPHEN C. BALDADO
Lay-out Artist

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GENEVA FAYE L. MENDOZA

BETA QA TEAM
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ZENAIDA A. ACADEMIA
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VICENTE B. MONGCOPA
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SYNOPSIS AND ABOUT THE AUTHORS

Electricity, magnetism, and light are interrelated concepts by virtue of the analysis that gave rise to Maxwell's equations. The continuous vibration of a charge yields a magnetic field that eventually yields an electric field. This alternate production goes on for as long as the charge is vibrating, resulting in the propagation of electromagnetic waves. Visible light is a form of an electromagnetic wave.

Total internal reflection or TIR as it is intimately called is the reflection of the total amount of incident light at the boundary between two media. The conditions for total internal reflection are: the ***light*** is travelling from an optically denser medium (higher refractive index) to an optically less dense medium (lower refractive index) and that the ***angle*** of incidence is greater than the critical angle.

ANSWER KEY

Pre-Test:

A.

1. Fastest
2. Fastest
3. Away from
4. Toward

B.

B, C, A

Evaluation/Post-test:

1. A
2. A
3. A
4. A
5. C
6. B
7. A
8. A
9. B
10. C
11. C
12. B
13. C
14. B
15. C

Jimma C. Porsuelo obtained her Master of Arts In Education major in General Science at Central Philippine State University- San Carlos City (2018) and her BSEd -General Science at Philippine Normal University-Visayas in 2008. Currently, she is a Senior High Shool teacher of JBCMHS-Main Campus teaching Science and Research subjects.

Rowena R. Dinokot graduated Bachelor of Secondary Education – Major in Biology at Jose Rizal Memorial State College, Katipunan Campus, Katipunan, Zamboanga del Norte last 2008. She also finished the degree Master of Arts in Education major in Administration and Supervision at Foundation University, Dumaguete City last 2018. Presently, she is teaching at Demetrio L. Alviola National High School (SHS Department) as Class Adviser of XII-STEM where she handled Sciences and Research.