Fiber Optics Activity

Subject Area(s) Physics & Physical Science

Yellow highlight = required component

Associated Unit N/A

Associated Lesson Letters from Hogwarts

Activity Title Sending a Message

Header

Image 1 **Image file:** ___? **ADA Description:** ___? **Source/Rights:** Copyright © ___? **Caption:** ___?

Grade Level 11 (10-12)

Activity Dependency Letter from Hogwarts

Time Required 30-50 Minutes

Group Size

Expendable Cost per Group US $ 5 (1/4" diameter 3' PETG plastic tubes available from McMaster)

Summary

Sending a Message is the application of the Letter from Hogwarts lesson. Students will split into 2+2 groups with a 3' long PETG cable shared between them. Groups will decide on a short morse code signal, establish a standard for signaling, and communicate their signal to the other group. End outcomes will learn about the equipment involved in fiber optic communications, the importance of clear and concise communication, and how the fundamentals learned in the physics classroom is applied to the real world.

Engineering Connection

Often in the classroom, students lose sight of why they are learning the material. With this lesson, the connection between the classroom and the engineering world is reinforced by showing how the simple idea of refractions has spawned a global market of fiber optics. Despite the simple principles behind fiber optics, its success did not happen overnight. Instead many areas of technological advancement (processing techniques, packaging, solid state physics for example) had to come together to make global communicate by fiber optics viable.

Engineering Category =

1. Relating science and/or math concept(s) to engineering

Keywords

Snell's Law, Fiber Optics, Light, Morse Code

Educational Standards

National and State

Choose standards from http://asn.jesandco.org/resources/ASNJurisdiction or browse educational standards on TeachEngineering.

State/national science/math/technology (provide source, year, number[s] and text):

Chapter 112. Texas Essential Knowledge and Skills for Science
Subchapter C. High School

Statutory Authority: The provisions of this Subchapter C issued under the Texas Education Code, §§7.102(c)(4), 28.002, and 28.025, unless otherwise noted.

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§112.31. Implementation of Texas Essential Knowledge and Skills for Science, High School, Beginning with School Year 2010-2011.

The provisions of §§112.32-112.39 of this subchapter shall be implemented by school districts beginning with the 2010-2011 school year.

Source: The provisions of this §112.31 adopted to be effective August 4, 2009, 34 TexReg 5063; amended to be effective August 24, 2010, 35 TexReg 7230.

§112.39. Physics, Beginning with School Year 2010-2011 (One Credit).

(7) Science concepts. The student knows the characteristics and behavior of waves. The student is expected to:

(D) investigate behaviors of waves, including reflection, refraction, diffraction, interference, resonance, and the Doppler effect;

Source: The provisions of this §112.39 adopted to be effective August 4, 2009, 34 TexReg 5063.

http://www.teachengineering.org/browse_standards.php Year 2009

- ***----------***
- ***National Science Education Standards: Science [1995]***
- ***Current Standard***
  - ***Content Standard E: Science and Technology (Grades K - 12)***
- ***Standard's Subset***
  - ***key:***
  - ***Link to ALL information for a standard***
  - ***Standard has one or more explicit curriculum alignments***
  - ***Content Standard E: As a result of activities in grades 9-12, all students should develop Abilities of technological design Understandings about science***

and technology
(Grades 9 - 12)

- ***----------***

ITEEA Educational Standard(s)

ITEEA (provide standard number, grade band, benchmark letter and text):

Standard 17. Students will develop an understanding of and be able to select and use information and communication technologies.
(Grades K – 12)

- ***L. Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information.***
  (Grades 9 - 12)
- ***M. Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.***
  (Grades 9 - 12)
- ***N. Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate.***
  (Grades 9 - 12)
- ***O. Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.***
  (Grades 9 - 12)
- ***P. There are many ways to communicate information, such as graphic and electronic means.***
  (Grades 9 - 12)
- ***Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.***
  (Grades 9 - 12)

Pre-Requisite Knowledge

Given the dependency on morse code through this lesson, the Letter from Hogwarts lesson is required and will cover any pre-requisites.

Learning Objectives

After this activity, students should be able to:

- Recognize components of a fiber optic system
- Be able to develop short morse code signals
- Be able to calculate the requirements for total internal reflection and recognize its important in the fiber optics industry

Materials List

Each group needs:

Each group should have:

- One laser
- One 3' PETG rod of at least ¼" thickness (diameter)
- One traditional semi-circle acrylic piece to study total internal reflection

Introduction / Motivation

Students, you saw in the previous Letters from Hogwarts lesson, the fundamentals of iber optic communication. Today we are going to use those principles to send signals from one another group to another and to apply what we learned. To make this a bit more interesting I want you to image that J.K. Rowling is contemplating an 8th Harry Potter book in which Harry, Hermione, and Ron, Ginny's and Draco's children James Sirius and Albus Severus and Lilly Luna Potter along with Hugo and Rose and Victoria and Fred and Roxanne Weasley and Scopius Malfoy are at the center of a twisted plot. In this installment, J.K. imagines that their children, who were selected to various houses in Hogwarts, will be forced to send each other code via a vast optical piping network about Hogwarts using their knowledge or critical angles, Morse code, and "nanometer" wavelength light waves that Professor McGonagall has taught them about. (The Owls are unreliable right now because they are being intercepted). (McGonagall lab is documented below – see if you are as astute as the young grandchildren and company). They/you must send a message to each other in secret and decode it to avoid certain peril.

Vocabulary / Definitions

Word	Definition
Electromagnetic Wave	A form of energy emitted and absorbed by charged particles which exhibits wave-like behavior as it travels through space
Refraction	The change in direct of a wave due to the transition from one medium to another
Reflection	The complement to the incident wave that is returned off the medium
Critical Angle	The angle at which total internal reflection takes place
Total Internal Reflection	The situation when no light is able to diffract out of a medium due to the critical angle being reached
Attenuation	The process of losing the intensity of a signal through such events as absorption, bending losses, and ablation of the material
Transmitter	In the context of fiber optics, a transmitter is the device that creates the light signal to be sent over the fiber optic cables
Receiver	The device, typically a photodiode, that receives the sent signal from the signal
Converter	The device that converts the digital light signal into a readable output.
Chromatic Dispersion	The refractive index is a function of wave length and as a result any signal that is a combination of wavelengths will refract to different degrees resulting in the separation of each individual wavelength
Bending Losses	When the angle of bending is significant enough to destroy total internal reflection
Ablation of Materials	When the material is damaged in such a way that total internal reflection is

	not maintained
Scattering	A general term referring to the interaction of waves with an object of the appropriate size scale (a house will scatter radio waves, electrons will scatter x-rays

Procedure

Background

Letter from Hogwarts covers all background necessary for this activity. The attached worksheet is to be followed.

Before the Activity

- Go over the Letters from Hogwarts lesson
- Set up an appropriate number of stations for groups of four. Each station should have a 3' piece of PETG rod, a laser and an acrylic semicircle. Most likely you will have ordered 6' long PETG rods that will need to be split in half due to attenuation.
- Split the class into groups of four, with two people being the sending team and two people being the receiving team
- Discuss laser safety and the what you want to accomplish (explain what the activity is)

With the Students

1. Sending team needs to establish a secret morse code message.
2. The sending and receiving team needs to establish a standard for length of pauses, dots, dashes, and spaces between sentences
3. Sending team sends there message and the receiving team records the message on the worksheet
4. After completion, the teams switch roles.
5. Finish the post lab assessment to reinforce lesson outcomes

Attachments

Fiber Optics worksheet

Safety Issues

- Lasers are present

Assessment

Please see the fiber optics worksheet that is meant to accompany the activity that contains both pre-activity, during activity, and post activity questions.

Activity Scaling

- Due to the nature of our GK-12 program we do not assign grading metrics but this can certainly be assessed.

Additional Multimedia Support

Fiber Optics PowerPoint from Letters from Hogwarts Lesson

References

http://media.techtarget.com/searchNetworking/downloads/FiberOptic_ch3.pdf

Other

Link of PETG rod - http://www.mcmaster.com/#catalog/119/3557/=oqxady

Redirect URL

Contributors

Brian Rohde, Don McGowan

Supporting Program

NSF GK-12 University of Houston,

Acknowledgements

Classroom Testing Information

Students in 1st, 2nd, 3rd, 4th, and 7th period Pre AP Physics at Friendswood ISD (30 per period). Testing took place in April of 2013.

Harry Potter Fiber Optics Worksheet Your Name _____ Period ____

Sending Group Members _____,_____
Receiving Group Members_____,_____

Activity background: Image if you will that J.K. Rowling is contemplating an 8th Harry Potter book in which Harry, Hermione, and Ron, Ginny's and Draco's children James Sirius and Albus Severus and Lilly Luna Potter along with Hugo and Rose and Victoria and Fred and Roxanne Weasley and Scopius Malfoy are at the center of a twisted plot. In this installment, J.K. imagines that their children, who were selected to various houses in Hogwarts, will be forced to send each other code via a vast optical piping network about Hogwarts using their knowledge or critical angles, Morse code, and "nanometer" wavelength light waves that Professor McGonagall has taught them about. (The Owls are unreliable right now because they are being intercepted). (McGonagall lab is documented below – see if you are as astute as the young grandchildren and company). They/you must send a message to each other in secret and decode it to avoid certain peril.

Background Questions

1. What is Snell's Law in words and formula?

2. What occurs when the critical angle is reached? What is the equation for critical angle?

3. What is chromatic dispersion? (Does the refractive index depend on wavelength?)

Fiber Optics Activity

Your job will be to pretend that each group is on team Gryffindor, team Slytherin, team Ravenclaw or team Huffelpuff and:

1. Establish with the other group what will be your "dot", "dash", and "space"
2. What is the message you are sending? (Between 10 and 30 characters/letters long) Remember to not verbally tell the other group you message.

3. What role does your brain play in this? Circle one (Converter, transmitter, fiber, receiver)
4. What role does your eye play in this? Circle one (Converter, transmitter, fiber, receiver)
5. What role does the laser play in this process? Circle one (Converter, transmitter, fiber, receiver)

6. What was the message that you received?

7. If the index of refraction for the fiber is 1.57 then what is the critical angle?

8. Use a protractor to try and determine the critical angle of a semicircular material different than the fiber (at what angle do you get total internal reflection?). After doing so back calculate the refractive index for the semicircular material.

a. Critical angle _____ degrees

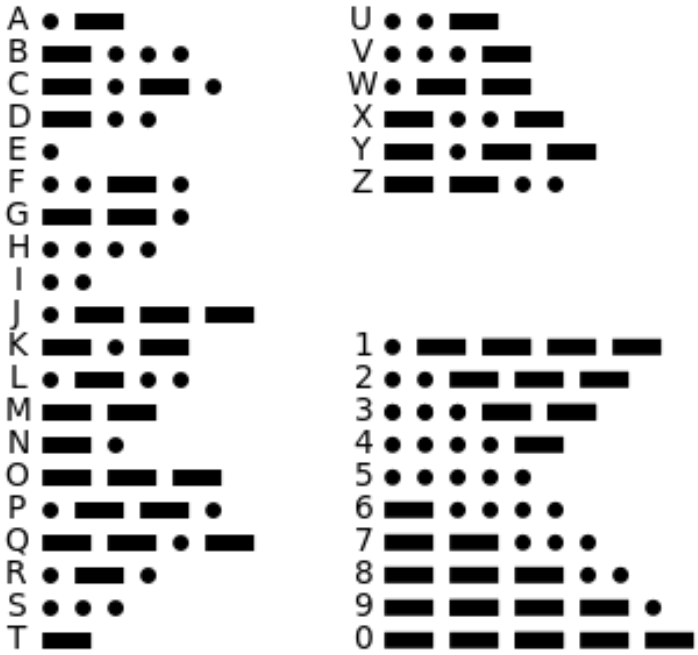
b. Refractive index

9. The red laser has a frequency of 4.2×10^{14} Hz. What is the wavelength of light in nanometers (10^{-9} m) given that $c = \lambda f$.

Some helpful information……

International Morse Code

1. The length of a dot is one unit.
2. A dash is three units.
3. The space between parts of the same letter is one unit.
4. The space between letters is three units.
5. The space between words is seven units.



Harry Potter Fiber Optics Worksheet Your Name _____**KEY**_____ Period ____

Sending Group Members _____,_____
Receiving Group Members_____,_____

Activity background: Image if you will that J.K. Rowling is contemplating an 8th Harry Potter book in which Harry, Hermione, and Ron, Ginny's and Draco's children James Sirius and Albus Severus and Lilly Luna Potter along with Hugo and Rose and Victoria and Fred and Roxanne Weasley and Scopius Malfoy are at the center of a twisted plot. In this installment, J.K. imagines that their children, who were selected to various houses in Hogwarts, will be forced to send each other code via a vast optical piping network about Hogwarts using their knowledge or critical angles, Morse code, and "nanometer" wavelength light waves that Professor McGonagall has taught them about. (The Owls are unreliable right now because they are being intercepted). (McGonagall lab is documented below – see if you are as astute as the young grandchildren and company). They/you must send a message to each other in secret and decode it to avoid certain peril.

Background Questions

1. What is Snell's Law in words and formula?

$n_i \sin \Theta_i = n_r \sin \Theta_r$

The ratio of the index of refraction of the two media are inversely proportional to the sine's of their angles.

2. What occurs when the critical angle is reached? What is the equation for critical angle?

At the critical angle there is no refraction only total internal reflection.

$n_i \sin \Theta_c = n_r \sin 90^\circ$ or $\sin \Theta_c = n_r / n_i$

3. What is chromatic dispersion? (Does the refractive index depend on wavelength?)

Different colors refract or bend at different rates when they encounter new media because refractive index depends on the wavelength or color of the wave.

Fiber Optics Activity

Your job will be to pretend that each group is on team Gryffindor, team Slytherin, team Ravenclaw or team Huffelpuff and:

1. Establish with the other group what will be your "dot", "dash", and "space"
2. What is the message you are sending? (Between 10 and 30 characters/letters long) Remember to not verbally tell the other group you message.
   Varies
3. What role does your brain play in this? Circle one (***Converter***, transmitter, fiber, receiver)
4. What role does your eye play in this? Circle one (Converter, transmitter, fiber, ***receiver***)
5. What role does the laser play in this process? Circle one (Converter, ***transmitter***, fiber, receiver)

6. What was the message that you received?
   Hopefully the same as sent.

7. If the index of refraction for the fiber is 1.57 then what is the critical angle?

   $\sin \Theta_c = n_r / n_i$ $\Theta_c = \sin^{-1}(1/1.57) =$ *39.6 degrees*

8. Use a protractor to try and determine the critical angle of a semicircular material different than the fiber (at what angle do you get total internal reflection?). After doing so back calculate the refractive index for the semicircular material.

a. Critical angle ____**43**_____ degrees

b. Refractive index

   $n_i \sin \Theta_c = n_{ir}$ $n_i \sin 43^\circ = 1$ $n_i = 1 / \sin 43^\circ = 1.47$

9. The red laser has a frequency of 4.2×10^{14} Hz. What is the wavelength of light in nanometers (10^{-9} m) given that $c = \lambda f$.

$c = \lambda f$ 3×10^8 m/s $= \lambda (4.2 \times 10^{14}$ Hz) $\lambda =$ *714 nm*

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