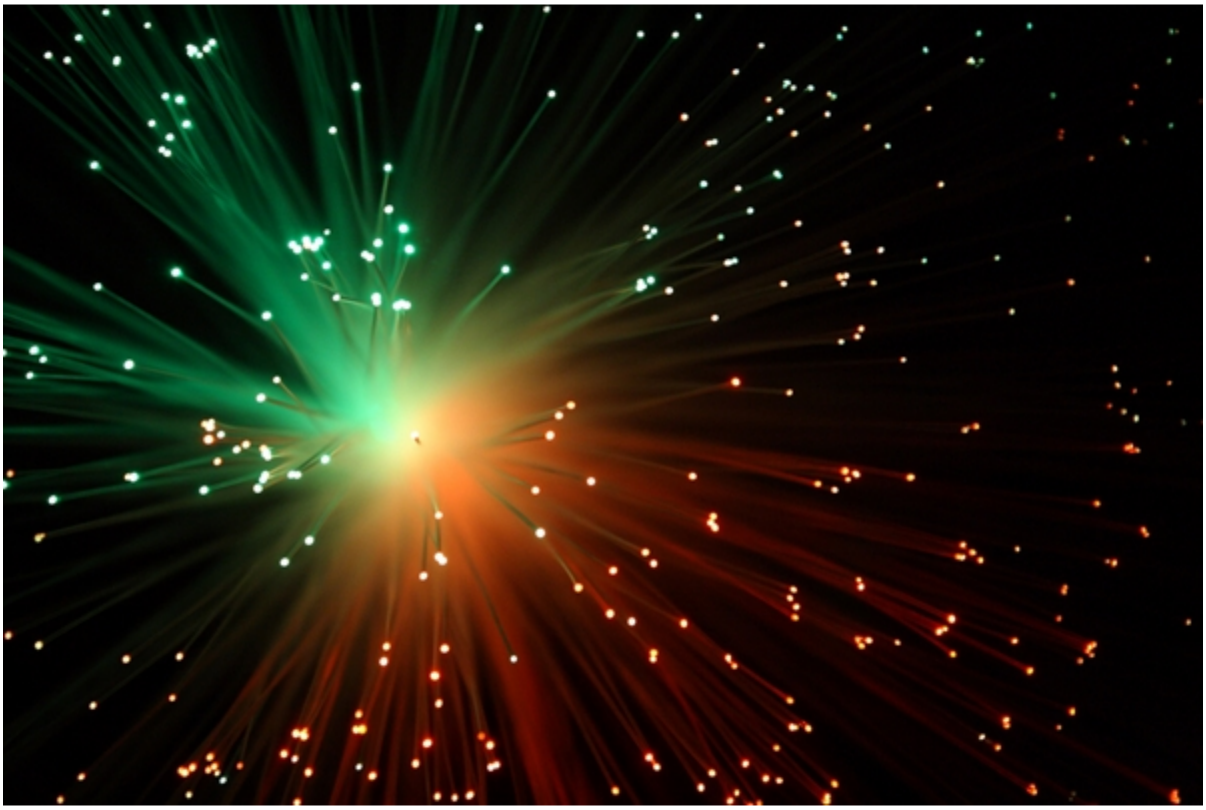
The Fibre Optic Cable Class

Learn about the amazing technology of fibre optics that has done so much for technology here on Earth and in observing space.

Amee Hennig, Center for Integrated Access Networks



AGE 10 - 14	**LEVEL** Middle School, Secondary
TIME 1h	**GROUP** Group
SUPERVISED Yes	**COST PER STUDENT** Medium Cost
LOCATION Small Indoor Setting (e.g. classroom)	**CONTENT AREA FOCUS** Astronomy
ASTRONOMY CATEGORIES Astronomical instrumentation, Astronomical databases, Galaxies	**SPACE SCIENCE KEYWORDS** Communications

CORE SKILLS

Asking questions, Planning and carrying out investigations

TYPE(S) OF LEARNING ACTIVITY

Structured-inquiry learning, Project-based learning, Modelling, Simulation focussed

KEYWORDS

Optics Fibre Optics Astronomy Sloan Digital Sky Survey Spectroscopy

GOALS

Students will learn the basics of how fibre optics work, the speed of light and total internal reflection. Students will also make the connection between fibre optics and astronomy and research technology.

LEARNING OBJECTIVES

At the end of these activities, students will be able to describe:
Activity 1:
- What is light and what are some of its uses
- How can light be used in technology
- How can light be used in Astronomy
- What is a total internal reflection and what are its uses in the real world and in astronomy.

Activity 2:
- What is a spectrograph and how does it work (i.e. where do fibre optics fit in).
- Give an example of where a spectrograph is being used and what is its function.

EVALUATION

- Students should be able to answer the learning objective questions.
- Students should be able to participate in Activity 1 & 2 with an understanding of the background of the technology (how it is used in SDSS) and results of that technology.
- Ask students to produce a poster or presentation for homework based on the practical. They should describe what total internal reflection is and an example of how it is used in technology and astronomy. From activity 2, they should also include what a spectrograph is and the function of optic fibres in it.

MATERIALS

For activity 1:

- Ball or container (capable of containing a small note or item)
- Note from the teacher (or other fun thing to put in the ball, i.e. a small toy)
- Multiple mirrors (one for all students)
- Laser Pointer
- Clear, plastic cord (that internally reflect laser light so it comes out the other end) or a length of fibre optic cable. Here's an example
- Fibre optic lamp, check this example
- Laser Safety Glasses (recommended)
- Laser Radio Communicator (optional). Can be made using the following instructions
- YouTube Video: Fibre Optic Cables: How they Work

For activity 2:

- Print-outs of Galaxy Fields document
- Scissors and/or handheld hole puncher
- String and/or pipe cleaners
- Paper plates
- Tape
- YouTube Video: Science Bulletins: Sloan Digital Sky Survey—Mapping the Universe
- YouTube Video: Tools of Astronomy Song

For activity 3

- Galaxy Zoo

BACKGROUND INFORMATION

Light is electromagnetic radiation that includes visible light (the rainbow that humans are able to perceive) and many other wavelengths of light that cannot be seen by the human eye such as gamma rays, x-rays, ultraviolet (UV) rays, infrared (IR) rays, microwaves, and radio waves. Visible light composes a significantly small portion of the full spectrum of electromagnetic radiation, or light, where roughly 400nm coincides with the colour violet (shorter wavelength) and 700nm coincides with the colour red (longer wavelength). Light is believed to travel faster than anything else in the universe at 186,000 miles per second (300,000 kilometres per second). However, this still has implications that limit the ability of anything to travel instantaneously. For example, although it seems that light from the Sun reaches us instantaneously, if the Sun were to suddenly go dark it would take about 8 minutes for anyone on Earth to realize this fact since there are about 93 million miles (149 million kilometres) between the Sun and the Earth.

These facts about light have effect on the transfer of information through technology as well as the study of astronomy. First of all, because light can travel the fastest of anything in the universe, this makes it a perfect medium to transfer information seemingly instantaneously. Optical fibres are new technology meant to take advantage of the speed of light to transfer information at these speeds. These fibres are flexible, extremely thin, transparent, and made with high quality extruded glass or plastic. This makes them a perfect option for transferring information through a variety of situations that may include turning corners or curves and protecting the information being transferred from outside impacts (that may block the information from reaching its destination). A common use for this technology recently is the internet. Through its use, internet speeds have been significantly increased and are more reliable. Additionally, this technology has been used to create the Fibre-Optic Link around the Globe which uses fibre optic cables laid out (mostly) along the ocean floor to connect the eastern coast of North American all the way to Japan.

This technology has also had many impacts on the study of astronomy. Some research tools in astronomy that use fibre optics include multi-object spectroscopy, bi-dimensional spectroscopy, high-precision radial-velocity spectroscopy, interferometry, and photometry. A deeper discussion of these uses may be found in the paper “The Astronomical Uses of Optical Fibers” appearing in the ASP Conference Series, Vol. 152 by Ian R. Parry. The Fiber Multi-Object Spectrograph (FMOS) is used in astronomy to collect light from many stars or galaxies at the same time allowing a wide range of information from a variety of targets to be viewed and collected simultaneously allowing for studies on galaxy formation and evolution as well as other studies. The Sloan Digital Sky Survey (SDSS) is one such example of how this technology is used to accomplish great things. Precise holes are drilled through a plate to go on the telescope so that the holes coincide with the many objects that will be observed at the same time. A fibre optic cable is inserted into each hole so that the light from each object, only, will be collected by that fibre optic cable and fed into a spectrograph which can then analyze the light from that object to learn more about it. In this way, thousands of objects in the universe are observed and precisely studied for their properties simultaneously. Beginning in 2000 the SDSS has had several phases during which more than a third of the night sky has been surveyed and spectra on over 5 million stars and galaxies has been collected. SDSS data is publicly available and is also used for educational programs as well such as Zooniverse’s Galaxy Zoo which invites anyone that wants to be a “Citizen Scientist” to investigate SDSS data to identify galaxies observed by SDSS.

FULL ACTIVITY DESCRIPTION

Getting Ready

Before the activity starts, have the teacher prepare a note or a fun little item to hide in the compartment in the ball. The students will stand for the demo and randomly arrange themselves about the room. After tossing the ball a path will be marked with a cord, mirrors will be passed out, and a laser pointer will be given to the starting student while the last student has a target.

Activity 1: Demo Walkthrough - Light and Fibre Optics

1. Begin with an explanation of the dangers of lasers and a safety requirement that all students be sure to use the laser responsibly. If laser safety glasses are available have students wear them, if not, perhaps limit the number of students using the laser and mirrors to fewer students to avoid any possible risk of the laser shining in anyone's eyes.

2. Start with everyone standing around the room randomly. Next, have the 'start' student yell something across the room to the 'end' student. Ask the students what they would have to do to get their message from the start to the end if they could not yell to the other person across the room.

3. Next have the 'start' student whisper their statement to the person closest to them, proceed to have each student whisper what was said throughout the room, going through every student, until it ends with the final student. Have the final student announce what was said by the original student. This is a good time to talk about the problems of different options of communicating and how sometimes the message may get 'garbled.'

4. Now give the ball with the note inside it to the first student and tell the students to begin tossing the ball through the room so that each person will catch it and pass it until it gets to the final student. Mark the path that the ball takes with the length of clear plastic cord. The final student will remove the note in the ball and announce what it says. Ask the students if there's anything that might be able to take the same path that the ball took and get the information to the end.

5. Hand out mirrors to everyone in the middle, a laser pointer to the starting person, and a target to the last person.

6. Tell the students that now they have to recreate the path the ball took, but with the laser pointer using mirrors to reflect the light to the target (WARNING: Do not shine lasers into eyes. Completely brief the students on the use of the laser before the activity begins, remind them once again at this point, and if possible include safety glasses.) This is a good opportunity to discuss photons in more detail.

7. Now challenge the students to get the laser from the first student to the last student in the same path that the ball took (use the cord on the floor to remember). Students will almost immediately realize that using this many mirrors to bounce the laser light will not work, end this part of the activity.

8. Now challenge the first student and two students between the last student to do the same, but only by bouncing the light off of their two mirrors to hit the target, this should be much easier.

9. (If the Laser Radio Communicator is being used) Switch out the regular laser with the laser radio laser and the target with the photoreceptor. Now have the students do the same so that by hitting the 'target' (the photoreceptor) they're hearing the radio.

10. Explain to the students how light can be used to transfer information. If the laser radio is being used you can explain that the brightness of the laser is changing so that the information about the sound of the music is what we hear. This can also be tied to the way that the patterns of 0's and 1's is used to transfer information like morse code and how the 1's and 0's could be the laser being bright or dark. Show the students that whenever the path of the light is blocked the radio stops showing that it's also an imperfect form of communication to lead into the next questions.

11. Ask the students if there's any other way we could get the laser light from one end to the other but with everyone. Encourage the students to think about the ideal situation, for example, if everyone could hold perfectly still but explain how this is not really a plausible situation. Encourage them to think about other ways it could be done until they begin to imagine surrounding the laser beam with a tube of mirrors. Ask if there is anything like this that they know of.

12. Tell the students to remember how they bounced the light, then ask them to pick up the cord on the floor and have the final student point the end of the cord at the target.

13. The first student should now take the laser s/he holds and touch it to the end of the cord while turning on the laser. The light should shine through the cord, reflect internally, and come out of the other end to hit the target. Ask the students what just happened. They should make the connection that the laser light is bouncing inside of the cord and moving through it until it gets to the end, just like their proposed solution of many mirrors surrounding the laser light.

14. Explain Total Internal Reflection. Some drawings on the board of the light internally reflecting throughout the cord may be useful.

15. If using the laser radio, ask the students if this method would work with the laser radio. Have the students switch the starting point and ending point once more with the laser radio, but this time shine the laser through the cord to hit the photoreceptor. Ask if there's some way to 'block' the signal now.

16. Ask if they know of something like this that is used today. After some responses bring out the fibre optic lamp and show them that this is exactly what's happening but on a smaller scale with these fibre optics transferring the light in the lamp.

17. This is a good point to show the video explanation from YouTube "Fibre Optic Cables: How they Work."

18. Now that the concept used in fibre optics is understood you can move on to explain how it is applied in the real world. The internet is one real world example that may be used. The following activity explains how fibre optics are used in astronomy.

Activity 2: Make a model of a Multi-object Spectrograph

1. Start by having the students watch the video about the Sloan Digital Sky Survey (SDSS) to learn about how fibre optics are used in combination with telescopes to take observations of many objects all at once.

2. Hand out to all students print-outs of 'galaxy fields' and scissors. The attached word document can be used and edited to make different types of fields that include stars and galaxies. Have the students use the paper to cut out matching holes in the paper plate (similar to how scientists manufacture the plates used in the SDSS shown in the video that collect light of individual stars as they correspond to the plates with fibre optics attached). This will help them understand the difficulty of precisely matching a star-field with the manufacturing of the SDSS plates for fibre optics.

3. After the students have cut out all of the 'galaxies' and 'stars' on their galaxy field they should observe the pattern of holes and see how the light shines through just like with the plates used by SDSS. Also discuss the difficulty of making precise holes for each star or galaxy and how much more precision and accuracy it must take for SDSS to accomplish this for hundreds of galaxies and stars on each plate that they make.

4. Next, pass out lengths of string and tape or pipe cleaners, tell the students to use the string/pipe cleaners like the fibre optics are used by SDSS to ‘plug in’ to the holes so that the light coming through the holes will be collected by the individual fibre optics for observation.

5. Ask the students to discuss the role of the plate and string/pipe cleaners in research. In other words, see if they can describe the process of the starlight entering the telescope, moving through the plate into the fibre optics into the spectrograph, and then the light being analyzed by the spectrograph to give the scientists information.

6. End by watching the YouTube video “Tools of Astronomy” and discuss the many ways that we have for observing the universe and how there are many different techniques for using technology to accomplish different goals. For example, this is a good lead in to further explain spectroscopy and how light may be used to identify the compositions of stars and galaxies.

Activity 3: Galaxy Zoo

1. An additional follow-up activity for students if computers are available is to introduce them to the Galaxy Zoo project. It should be noted to the students that Galaxy Zoo is not the result of observations from SDSS using the Multi-object spectrograph but just another example of how useful surveys such as this are to study the universe in a variety of ways as well as how light can tell us many different things about an object being observed.

2. Have students work in groups (depending on how many computers are available) to go through the Galaxy Zoo tutorial and project to learn about how SDSS data is publicly available and has been developed into a citizen science project for classifying galaxies.

3. Encourage students to continue participating in citizen science and galaxy zoo at home, and remember all the hard work that goes into developing the technology to collect this information as well as the hard work that goes into the actual collection of this information.

CURRICULUM

Country	Level	Subject	Exam Board	Section
UK	KS3	Physics	-	Waves: Light waves
UK	KS2: Year 6	Science	-	Light

USA

This activity either discusses or relates to topics included in the new Next Generation Science Standards in the USA. Additional materials may be added by the teacher to further tie these activities to a variety of the following topics. More information on these may be found at

- http://www.nextgenscience.org/msps-wer-waves-electromagnetic-radiation
- http://www.nextgenscience.org/hsps-wer-waves-electromagnetic-radiation
- http://www.nextgenscience.org/hsess-ss-space-systems

Middle School:

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2)
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2)

PS4.C: Information Technologies and Instrumentation

- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)

High School:

PS4.A: Wave Properties

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2),(HS-PS4-5)
- [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3)

PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3)

PS4.C: Information Technologies and Instrumentation

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5)

ESS1.A: The Universe and Its Stars

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2),(HS-ESS1-3)

PS4.B: Electromagnetic Radiation

- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.(secondary to HS-ESS1-2)

ADDITIONAL INFORMATION

- The Astronomical Uses of Optical Fibers by Ian R. Parry
- USA Next Generation Science Standards
- Laser Radio Communicator
- YouTube Video Fiber Optic Cables: How they Work
- YouTube Video Science Bulletins: Sloan Digital Sky Survey—Mapping the Universe
- YouTube Video Tools of Astronomy Song
- Galaxy Zoo
- How Fiber Optic Cables Work: An Animated Guide by The Bookmark

CONCLUSION

Students should better understand the basic concepts of light, total internal reflection, fibre optics, and how light and technology (fibre optics) is used in astronomy (specifically, a better understanding of SDSS and spectrography). They should be able to answer the questions above and share ideas about how fibre optics are useful for studies in astronomy. Discussion topics are included throughout the walkthrough and include:

- Methods of communication using technology
- Problems with methods of communication, and solutions
- Light as a method for communication
- Uses of total internal reflection
- Uses of fibre optics in astronomy research technology
- Real-world examples of use such as the Sloan Digital Sky Survey
- The basic function of the Sloan Digital Sky Survey to collect spectrograph information
- The uses of the information gathered by the Sloan Digital Sky Survey
- The importance of surveys like the Sloan Digital Sky Survey (i.e. mass collection of research data)
- The challenges of creating technology for research as well as everyday communication

ATTACHMENTS

- Galaxy Fields RTF
- Galaxy Fields PDF

ALL ATTACHMENTS

All attachments

CITATION

Hennig, A., 2015, *The Fibre Optic Cable Class*, astroEDU, , doi:10.14586/astroedu.1411

ACKNOWLEDGEMENT

Allison Huff Mac Pherson, Danny Lamoreaux, Image credit: Galaxy Zoo, Mal_irl