HANDS-ON OPTICS TRAINNING COURSE
Vigo, Spain, April 3 to 11, 2009

Introduction to Optics

Experiments Guide (2)

EXPERIMENTS:

Index

EXPERIMENT NO. 1.

Title:

Light sources.

Aim:

Students will be presented with a few concepts related to light and to the generation of light.

Equipment:

Optical table; light source; laser pointer; ultraviolet lamp*; remote control*; fluorescein paper strip*; fluorescence rock; phosphorescent fibre; plastic coloured filters; glass*; water*; object.

Procedure:

Look around you.

You see a set of objects. Some of these objects are brighter, and some of them are darker. Some are transparent, while some are opaque, and some of them are translucent. They are many colours and shapes.

If somehow you managed to turn the light off (shut down all the sources of light (!)...) you could predict what would happen ... Everything around you would disappear, and the same would happen if you closed your eyes ... There would be no sources of light and no visual perception...!

1. Identify the several sources of light provided to you, and the natural sources of light around you. **(REMEMBER: NEVER LOOK DIRECTLY AT THE SUN OR THE LASER BEAM! And never look at a bright light for more than just an instant).**

Can you tell the differences between them? (Sun, fluorescent lamp, light bulb, candle flame, laser...)

2.

a) Place a little fluorescein in a small glass with water, and shine the flashlight inside the glass.

What happened?

b) Successively, place several filters of different colours (small plastic colour sheets) in front of the flashlight and shine the flashlight inside the glass again. Do you see any differences?

c) Now light the glass with the ultraviolet lamp.

What conclusions can you draw?

d) Shine the ultraviolet light on other objects such as a bank note or the fluorescence rock that has been provided to you.

What do you see?

e) Turn off the light now.

Can you see anything in the dark?

f) Shine the ultraviolet lamp on the phosphorescent fibre.

g) Turn off the light to darken the room a little.

What do you see?

Conclusions:

Comment on the work you have done, and identify the different types of light generation that you have observed.

EXPERIMENT NO. 2.

Title:

The optical prism

Aim:

The students will be encouraged to explore the function and the characteristics of optical prisms.

Equipment:

Optical table; light source; laser pointer and laser holder; prism; diaphragm; object.

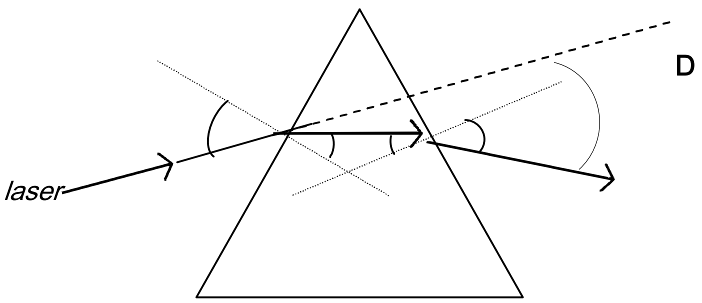
Process and results:

a) Place the light source on the optical table, and turn it on. Then, place the diaphragm at the front slit of the light source (keep the lateral slits closed).
Place the Newton prism only a few centimetres from the slit. Then, place the object a little further away, and as you move it around the prism try to create something similar to a rainbow.
Write down a plan that represents the position and orientation of the light source, the prism, the object, and the path of the light beam, and describe the image you see on the object.

b) Place the laser pointer on the laser holder next to one of the sides of the optical table. As you turn it on, you will see a red line over the table. Then, place the flat wedge on the table as shown below.

c) Turn the wedge very slowly around itself and see what happens to the emerging beam. Now turn it in the other direction. You can try this a few times until you notice that there is a position in which the emerging beam no longer deviates from the incident direction (which is the original direction of the beam that enters the wedge). In that position, angle D is called "minimum deviation" and characterizes the wedge.

d) The Newton prism allows you to observe a very interesting effect as well.
Place the prism over the optical table and look at it from above.
What do you see?
Place the coloured triangles under the prism and look at it from above again.
The effect you observe is called the "kaleidoscope effect".
Can you explain how it works? (Keep in mind what you observed before placing the coloured figures under the prism).



Conclusion:

Comment on the work you have done:

____

____

____

____

____

____

EXPERIMENT NO. 3.

Title:

Dispersion.

Aim:

The students will be presented with another feature concerning the nature of light. The spectrum.

Equipment:

Optical table; flashlight; Newton' prism; pocket spectroscope; light sources.

Procedure:

It is possible to separate light into a band of colour called a spectrum by aiming it at a prism or at what we call a "diffraction grating".

Place the prism on the optical table.

If it's sunny, bring it near a window so the rays can pass through. If not, use your flashlight.

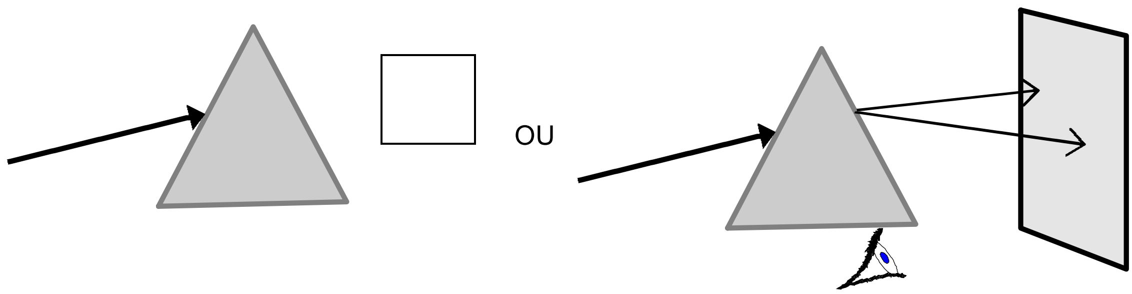
What does the emerging beam look like?

It'll be much easier if you darken the room a little, and if you keep turning the prism clockwise.

1) Write down the colours you observe in order of appearance.

Try to observe other kinds of light source through the prism, such as fluorescent and/or neon lamps or lamps of other kinds when available.

2) Do you think every colour is present in the "spectrum" you observed?



3) A spectroscope is a special device that allows you to observe the spectral composition of light in a fairly easy and efficient way.

The colours you see in the spectrum of an object are specific to that same object. In order to identify an unknown material, scientists compare its spectrum to the pattern-spectra of different materials. This process is called spectroscopy, and can be used in several ways. For instance, today it is possible to study the chemical composition of a particular star simply through the spectroscopic analysis of its light without even travelling there!

Repeat this experiment using the pocket spectroscope.

EXPERIMENT NO. 4.

Title:

The human eye

Aim:

The students will learn to recognize the constitution of the human eye, and study some of its characteristics.

Equipment:

Flat mirror; concave mirror; a proper device to observe the eyeball; optical illusion cards.

Process and results:

I'm sure you are familiar with the anatomy of your eye and with the way it works. Still, let's check.

1) Hold the flat mirror at a comfortable distance and observe one of your eyes. You can use a curved mirror to magnify the image of your eye if you want to.

1.1) Identify the different parts of your eye, and draw a simple diagram.

1.2) Discuss the role of each part.

2) Now, listen to your teacher's instructions very carefully, and observe the interior part of your eyeball with the help of a proper device.

2.1) Slowly bring the device towards your eye, and observe (you should stop as soon as the device reaches your eyelashes! Don't forget: your eyes are as fragile as they are important!).

2.2) Take notes and describe everything you observe. Comment on the results with your teacher.

3) You will now analyze a few characteristics of the functioning of your eyes.

3.1) The blind spot.

Hold this sheet with your arm stretched out in front of you, and close your left eye. Focus on the centre of the cross. You should be able to see both images (the cross and the circle).

Slowly bring the sheet towards your eyes. Suddenly ... where has the circle gone?

+ **O**

3.2) Binocular vision.

Hold a pencil in your hand, and stretch out your arm in front of you. Close one of your eyes and check the position of the pencil. Now close your other eye. What is the position of the pencil?

Comment on the differences.

3.3) Optical illusions...

Your teacher will provide a set of cards. Watch them closely. What do you see?

Have fun!

Comment on the work you have done.

EXPERIMENT NO. 5.

Title:

The visual perception of colours.

Aim:

The students will analyze mechanisms related to the visual perception of colours. The addition of colours.

Equipment:

Triple light source; Filters of different colours; Neutral Filters; Object.

Process and results:

The process through which the human eye perceives colour is somewhat complicated, but in general terms the sense of colour is obtained through the stimulation of 3 types of sensors (cones) placed near the centre of the retina (in the fovea).

We have said previously that every type of light is associated with a wavelength or even with a range of different wavelengths. Well, each one of these sensors is sensitive to almost every wavelength (of the visible range), but its highest level of sensitivity occurs only with a narrow range of wavelengths. One of them is particularly sensitive to the wavelengths associated with blue, the other one to those associated with green, and the other one to those associated with red.

It is this set of stimuli that allows the brain to determine the colours of the objects we see.

Mixing colours.

1. An object has a certain colour if: it emits, reflects or transmits (allows to pass) light of that particular colour. For instance, a green cellophane sheet is green because it absorbs every other colour, and reflects or allows only the green light to pass on. What do you think would happen to the health of a green plant if it were illuminated only by a green light?

____

____

____

____

I'm sure you know that if you mix paint of two different colours (or more) you will get a colour that is different from the colours you mixed.

2. We will now discuss the problem of adding colours.
It is said that with three colours (the main ones) it is possible to obtain every other colour, simply by varying the relative amounts of each colour. This is not absolutely true, but almost...
The main colours are blue, green and red.
Yellow is not! Let's see why.

2.1. Place the red filter at the left slit of the triple light source, and the green filter at the front slit (or vice versa). Place the yellow filter at the right slit. Set the mirrors so that the red and green beams coincide on the object, and the yellow beam shines right next to them. Both images will be yellow, and probably very similar!

2.2. Now, place a well-lit red sheet in front of your eyes. Let your eyes get used to the red. Remove the sheet quickly, and look at the object where the two yellow images are. What do you see?

____

2.3. Now place a green sheet in front of your eyes, and repeat the process. What colours are the images now?___________________________!

2.4. Confirm if the yellow stains have different origins/compositions. Try to obtain their spectra through the prism or the spectroscope like you did before.

____

____

____

____

2.5. Replace the yellow filter with the blue one. Turn the mirror, and add the blue beam to the red and the green beams. What colour do you obtain?____

2.6. Switch the filters, try to alter the intensity of each beam (ask your teacher for some advice), and block each beam successively in order to obtain as many colours as possible. Write down the most interesting things you see. For instance: red+green=_______; r+blue=________; g+b=________ (the three colours you will obtain are important as well...);

____

____

____

____

____

2.7. Replace the object with coloured sheets. What are the differences?

____

____

____

____

____

Keep in mind that different people may see different colours.
Warn your teacher if you think that a member of your group is having problems with this experiment.

Some of the results you obtained may not have corresponded to your expectations as far the addition of colours is concerned. Every paint has a particular colour because it absorbs and subtracts the other colours. For instance, if you mix red, green and blue paint you will get a very dark colour, almost black (because these three pigments together absorb the light that falls upon them). Have you noticed that when you mix red, green and blue light beams you get a beam that is almost white?

EXPERIMENT NO. 6.

Title:

The independence principle of luminous rays

Aim:

Attention will be drawn to this basic principle of geometric optics.

Equipment:

Optical table; triple light source; colour filters; object.

Procedure

Place the triple light source on the optical table.

Place a filter (slide) in front of each slit. They should be different colours (for example green, red and blue).

Open the three slits, and set the mirrors so that the beams coincide.

You see very interesting things on the object where the beams coincide, but we'll come back to that later...

For now, what we need to know is whether the beams change after they coincide; that is, if the beams remain the same colour - if the red remains red, if the green remains green...

What do you think?

Get to work and check your results!

EXPERIMENT NO. 7.

Title:

The principle of reversibility.

Aim:

The students should be able to demonstrate the basic principle of reversibility, and to recognize that it is more important in people's lives than they suspect...

Equipment:

Mirror.

Procedure

I'll start by asking you an indiscreet question.

Have you ever observed anyone in a mirror?

If you haven't... you'll be doing it now!

Place a mirror (preferably a large one) on the table. Use it to see one of your classmates.

Ask your friend what s/he sees when s/he looks at the mirror!

Try it with other classmates.

Conclusion... ?____

____

____

____

EXPERIMENT NO. 8.

Title:

Refraction

Aim:

Introduction to refraction.

Equipment:

Optical table; laser; glass block; water tank; glass or cup; water; metre stick.

Procedure

Place a coin in the bottom of a cup, and move slightly away until you stop seeing it. Slowly add some water to the cup.

What happened?

Can you explain why?

____

____

____

____

____

No?!...

Place the glass block on a sheet of millimetre paper. Look at it from above. The paper lines seem to have _____________.

Lay the glass block on the sheet of millimetre paper. Shine the laser beam collaterally onto one of the sides of the glass block, and close to the paper (a red line will appear over it). The beam will cross the glass block and emerge from the other side. Draw the outline of the glass block and the beams on the paper.

The incident direction of the beam changed as it entered the glass block and as it emerged from it. You see, glass has a higher optical density (refractive index) than air (and the same happens to water). Thus, light will propagate in a slower way inside the glass, and will stay inside as briefly as possible.

At the point of incidence of the laser beam, that is, where the beam and the first side of the glass block meet (dioptre - the surface of separation between two media with different refractive indices), draw a line segment perpendicular to the side of the glass block (this line segment is called the normal). Compare the inclination of the incident beam in relation to the normal with the inclination of the beam inside the glass.

Repeat the process for the second dioptre (glass/air).

When a light beam travels from a higher refractive index medium to a lower refractive index medium, the direction of propagation __________ the normal, which is perpendicular to the dioptre. On the other hand, when a light beam travels from a lower refractive index medium to a higher refractive index medium, the direction of propagation __________ the normal. (approaches or deviates from?)

Let's go back to the coin in the bottom of the cup...

It's the refracted beams that travel towards your eyes. Try to draw the path of the emerging beams. Your brain assumes that the rays propagate in a straight line, and does not consider that the path of the emerging beams might deviate once it passes the surface of separation between the water and the air. Therefore, the coin seems to have emerged!

EXPERIMENT NO. 9.

Title:

Reflection.

Aim:

Introduction to one of the most important phenomena in geometric optics: light reflection.

Equipment:

Optical table; tape-measure or metre tick; beam-splitter*.

Procedure

Place the beam-splitter (optical device that splits a beam of light in two so that a half of that light is transmitted, and the other half is reflected) on a piece of written paper. Place yourself a little above the paper and look at the beam-splitter. Not only will you notice that you can see what's behind it, but you can also that see what's written on the piece of paper, because it's reflected on the beam-splitter.

Where do you think the reflected image is?

Draw a small image (a cross, for instance) on a piece of paper (3 or 4 cm from the centre of the sheet), and place the beam-splitter at the centre of the sheet.

Observe carefully.

With a pencil draw the position of the image you see in the mirror.

What conclusions do you draw about reflection?

EXPERIMENT NO. 10.

Title:

The law of reflection.

Aim:

One of the first laws...

Equipment:

Optical table; laser; laser holder; protractor*; setsquare*; flat mirror.

Procedure

Place a sheet of millimetre paper on the optical table.

Draw a line at the centre of the sheet and place the flat mirror on it.

Place the laser on the laser holder next to the table, and aim it at the mirror.

Turn on the laser (never forget the precautions you should take when working with lasers!) and observe how the beam that falls upon the mirror is reflected.

With a pencil draw the incident and the reflected beams, and then remove the sheet.

Draw a line perpendicular to the mirror (the normal) where the two lines meet (point of incidence)

Now measure the angle between the incident beam and the normal, and the angle between the reflected beam and the normal. Compare them.

What conclusions do you draw?

EXPERIMENT NO. 11.

Title:

Mirrors

Aim:

Reflections and reflection.

Equipment:

Optical table; bendable plastic mirror; laser pointer; tape-measure or metre stick; white object; metal spoon.

Procedure

FLAT MIRRORS

I'm sure you see flat mirrors every day (and you see yourself in them). And you probably have wondered which side is the right side of the image in the mirror...

Place the mirror at the centre of the optical table.

Place the laser on the laser holder next to the optical table so that you can see a red oblique line (the laser beam) travelling over the table towards the mirror.

Observe the reflected beam, and draw the position of the mirror, of the incident beam and of the reflected beam on the table.

Based on what you have seen, how would you explain reflection? How does the mirror affect the light beam?

I'll leave you with a game now...

IMAGES IN CURVED MIRRORS

Start by placing the bendable mirror, as flat as possible, about 1.5 m from your face.

You'll notice that you can mould the mirror into several shapes. For instance, if the edges of the mirror are closer to you, the mirror is CONCAVE. On the other hand, if the edges of the mirror are further from you, the mirror is CONVEX.

1) Try to create a normal but rather narrow image of your face. Explain what you did.

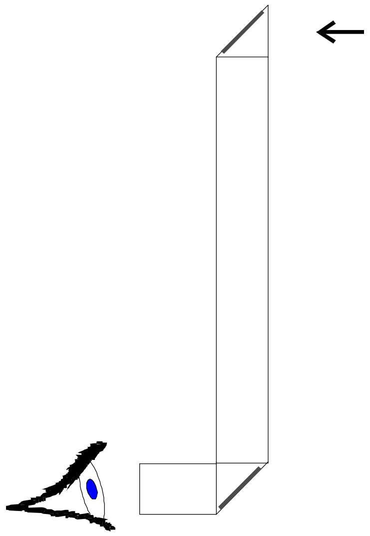
2) Now try to create an inverted image. Explain what you did, and point out the differences in the mirror you used.

3) Try to create an image of your face with four eyes, and explain what you needed to do.

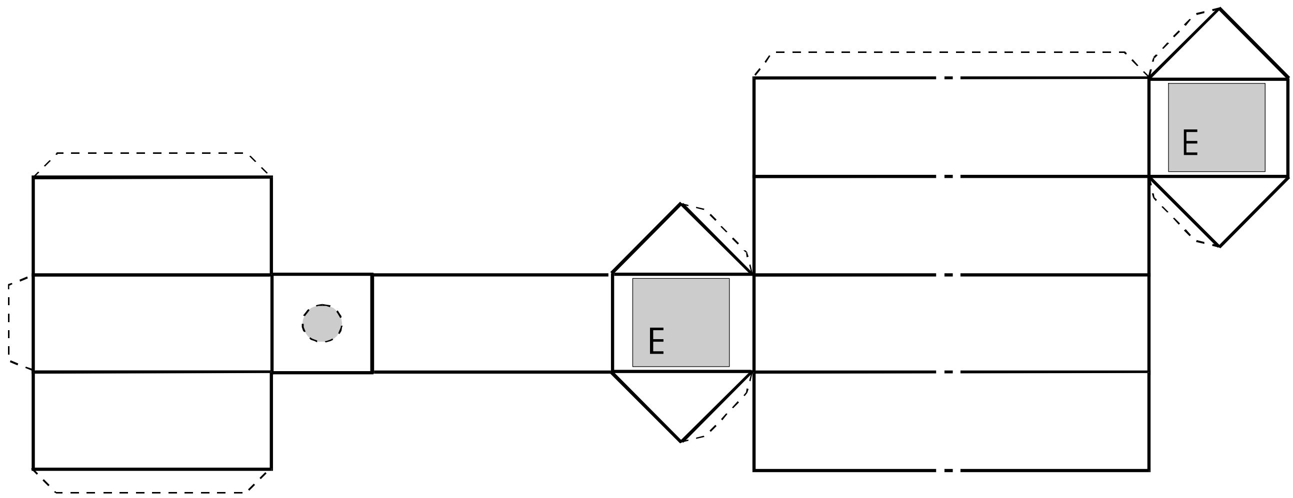
4) Try to create other kinds of images and have fun.

5) Place a pencil in front of a spoon, and try to create images on both sides.

Last, but not least, I suggest you set up a periscope (what is it used for by the way?)



Copy this diagram onto a large bristol board (it'll be better if it's black on the inside), stick two mirrors in the positions you see in the image below, trim the bristol board and set up your periscope.



EXPERIMENT NO. 12.

Title:

Introduction to geometric optics

Aim:

The students will be presented with a few elements and terms used in geometric optics, such as light sources, lenses, apertures, the concepts of object, image, focus...

Equipment:

Optical table, light source, positive lens (A), aperture (diaphragm), slide, object.

Process and results:

a) Place the light source at the edge of the optical table, and turn it on. Then, place the object on the object marker and slide it along the optics bench.

Briefly describe what you see.

---

b) Place a circular 0.01 m diameter aperture in front of the light source.

The light that emerges from the aperture will be the object.

Describe the image that will be formed on the object.

c) Replace the diaphragm with the slide (which will be the object from now on).

Describe the image that is formed on the object.

d) Place the lens between the aperture and the object. Slide the lens, the object or both until the image is focused.

Describe the things you observe and the focused image.

Conclusion:

Comment on the work you have done.

EXPERIMENT NO. 13.

Title:

Lenses

Aim:

Students recognize the use of lenses as a means to obtain clear images.

Equipment:

Optical table; light source; lenses A, B and C; slide, tape-measure or metre stick; white object.

Procedure:

Darken the room a little, and try to find the image of a luminous object formed by a lens (lens A).

1. a. Place the luminous object more than one metre away from the lens.

b. After placing the object behind the lens, move it back and forth until you get a sharp image of the object (focusing).

Describe the focused image and write down the differences between the image and the real object.

2. Repeat the previous steps, now using lens B.

Describe the image.

3. Finish your experiment using lens C.

Write down all the differences between the object and the images obtained.

4. Using lens A, and keeping the positions used for the previous experiments, gradually reduce the distance between the object and the lens. Move the object to focus the images.

Write down the things you see, and try to understand how the reduction of the distance between the lens and the object affects the size and location of the image.

We will now focus on one of the most important characteristics of the lenses: focal length.

The image of an object placed far from the lens will be formed on a spot called the focal point of the lens. The distance from the "centre" of the lens to the focal point is called the focal length.

5. Determine the focal length of lenses A and B.

Think of the best way to do this.
Plan your own experiment, and put it into practice.
If somehow your experiment doesn't work the first time, watch everything carefully to identify what went wrong. Think how you can correct (or improve) things and get to work!

Have fun!

EXPERIMENT NO. 14.

Title:

Magnifying lenses. The magnifying glass.

Aim:

The students will be presented with one of the most important features of lenses: magnified images.

Equipment:

Optical table; light source; laser pointer; lenses A, B and C; tape-measure or metre stick; white object.

Procedure

1. For each of the three lenses:

a. Place the lenses one by one on the letters of a printed book.

b. Slowly lift the first lens and look through it. Do the same for the other lenses.

Describe the images of the letters you have observed through each of the three lenses:
What happens to the images as you move the lenses back or forth?

2. Now, hold each lens close to one of your eyes.

Are the letters in the printed book bigger or smaller than the object or the same size?

Can you tell from this experiment which lens or lenses could be used as a magnifying glass?

Summarize the different behaviour of each lens.

3. One at a time, place close to your eye only the lenses that can be used as a magnifying glass. Move the paper until the letters get as big as possible. This is the correct way to use a magnifying glass!

4. Observe small objects using your magnifying glasses.

Draw the objects in real size, and then draw the images obtained with the magnifying glasses.

EXPERIMENT NO. 15.

Title:

The microscope

Aim:

Students will set up and study a microscope.

Equipment:

Optical table; Lenses A and C; tape-measure or metre stick.

Procedure

You will set up a microscope using lenses A and B.

Hold lens B close (2 to 3 cm) to this sheet for example.

Hold lens A (eyepiece) close to your eye.

Move toward lens B at a distance of about twenty centimetres. Move lens B slightly back or forth (the objective lens), until you get a sharp image of the paper sheet.

(You can support the lenses on the optical table, and attach the object you will observe to the object if you want to.)

1. Describe the image you observe with the microscope and compare it to the real object.
2. Draw the object and the image you observed on the same sheet.
3. Measure (estimate) the length of each, and try to figure out the relation between the size of the image and the size of the object.

(Keep the magnifying glass in mind)

What conclusions do you draw?

In your own words explain what a microscope is.

EXPERIMENT NO. 16.

Title:

Telescopes (Part I). The Galilean Telescope.

Aim:

Introduction to the Galilean telescope.

Equipment:

Optical table; Lenses A and C; tape-measure or metre stick.

Procedure

You will set up a Galilean telescope using lenses A and C.

Hold lens A with your left hand and lens C with your right hand (or vice-versa).

Start by holding lens C close to your eye so that it almost touches your eyebrow, and aim it at a distant object (REMEMBER: it is extremely dangerous to look at the sun!)

(You can support the lenses on the optical table if you want to.)

Slowly hold lens A close to the same eye until you get a sharp image. If necessary (and it probably will be, but it only takes a little patience...) move the lens slightly back or forth until you manage to focus the distant object clearly (estimate the distance between the two lenses and write it down.)

1. Describe the image you see through the telescope you set up, and compare it to the object.
2. Draw the object and the image you observed on the same sheet.

3. Measure (estimate) the length of each, and try to figure out the relation between the size of the image and the size of the object.

What conclusions do you draw?

In your own words explain what a telescope is.

EXPERIMENT NO. 17.

Title:

Telescopes (Part II). The Keplerian Telescope.

Aim:

Introduction to the Keplerian telescope.

Equipment:

Optical table; lenses A and B; tape-measure or metre stick.

Procedure

You will set up a Keplerian telescope using lenses A and B.

Hold lens A with your left hand, and lens B with your right hand (or vice-versa).

Start by holding lens B close to your eye until it reaches your eyebrow, and aim it at a distant object (REMEMBER: it is extremely dangerous to look at the sun!)

Slowly hold lens A close to the same eye until you get a sharp image. If necessary (and it probably will be, but it only takes a little patience...) move the lens slightly back or forth until you manage to focus the distant object clearly (estimate the distance between the two lenses and write it down.)

1. Describe the image and compare it to the real object.
2. Draw the object and the image you observed on the same sheet.
3. Measure (estimate) the length of each and try to figure out the relation between the size of the image and the size of the object.

What conclusions do you draw?

Identify the differences between the Galilean and Keplerian telescopes.

Use both telescopes alternately to observe objects at different distances (some at short distances - 5 to 10 m - and some at much longer distances).

Compare the results, and choose a telescope for each situation.

EXPERIMENT NO. 18.

Title:

The Fresnel lenses.

Aim:

Students should be able to recognize that not every lens needs curved surfaces.

Equipment:

Optical table; lenses A, B and C; Fresnel lens; tape-measure or metre stick; object.

Procedure

Observe the Fresnel lens carefully.

1. What are the differences between this lens and the other lenses you have already worked with?
2. Do you think the Fresnel lens is a magnifier?

Work with it for a while, and then write down your conclusions!

Let's try to figure out the focal length of this lens:

Bearing in mind a previous experiment in which you determined the focal length of some lenses, determine the focal length of the Fresnel lens.

3. Compare the focal length of both lenses.

How to make a telescope using the Fresnel lens...

Bearing in mind the previous experiments try to set up a telescope.

Will you set up a Galilean or a Keplerian telescope? Why?

Try the telescope you chose and then check your results.

What is your opinion of the Fresnel lens?

EXPERIMENT NO.19.

Title:

The slide projector.

Aim:

The students will learn that lenses have many applications...

Equipment:

Optical table; light source; Fresnel lens; lenses A and B; slides; metre stick; object.

Procedure

You are now going to build a slide projector.

Place a slide in front of the front slit of the light source.
Place lens A a few centimetres from the slide, and the object a little further away.
Try to focus the image on the object. You might have to move the object, and probably the lens as well.

1. Compare the image to the object.

Repeat the whole process using lens B.

2. Which lens provides a better image?
3. What helped you decide?
4. Try to focus the image after moving the object (about 2 metres from the lenses).
5. Describe the images obtained with both lenses, and write down the differences.

Briefly comment on the work you have done.

Well, now.... there's not much of a difference between a slide projector and an animated projector!
Have fun!

EXPERIMENT NO. 20.

Title:

Cylindrical lenses.

Aim:

Students use their observational skills and critical judgement so that they can discuss the effects of using cylindrical lenses.

Equipment:

Optical table; light source; laser pointer; cylindrical lens; object of reference; glass cylinder, water, object.

Procedure:

1. Hold the laser pointer with your hand, and aim it at the ceiling (be careful with your eyes and your friends'!). Now hold the cylindrical lens at the slit of the laser beam.

What happened to the shiny dot that was formed on the ceiling?

Turn the lens, and see what happens to the red line that appears gradually on the ceiling.

Draw a diagram that represents what you observed (What is the orientation of the lens in relation to the glass cylinder?).

Now fill the glass with water, and shine the laser beam horizontally on it.

Comment on what happens.

2. Now place the reference object in front of the light source on the optical table.

Place the glass (the cylindrical lens you have is too small...) about 0.15 m from the object, and try to focus the image.

Describe the image. Is there anything special about these images when compared with those obtained in a previous experiment using spherical lenses?

Results:

Describe the experimental process you have developed.

Based on your results and the aim of this experiment, discuss the function of cylindrical lenses.

EXPERIMENT NO. 21.

Title:

Diaphragms and lenses.

Aim:

Students use their observational skills and critical judgement so that they can discuss the influence of the use of diaphragms in optical systems

Introduction to the concept of the pupil.

An emphasis on the importance of using diaphragms in several optical instruments, such as photographic cameras.

Equipment:

Optical table; light source; lens B; diaphragms; slide or object of reference; object.

Procedure:

1. Place the reference object in front of the light source.
2. Place lens A at a distance of about 0.15 m from the object. Secure the object and focus the image on it.

Describe the image (size, orientation, position, brightness...).

3. Place the 0.005 m diameter diaphragm 0.1 m in front of the lens.

Describe the image. What's changed?

4. Place the diaphragm 0.01 m in front of the lens now.

Describe the image.

5. Replace the current diaphragm with a 0.005 m diameter diaphragm and place it 0.02 m in front of the lens.

Describe the image.

6. Place the diaphragm 0.1 m in front of the lens again.

Describe the image.

7. Compare the images you've obtained. What conclusions do you draw?

8. Place the 0.01 m diameter diaphragm 0.1 m behind the lens.

Describe the image.

9. Now place it 0.02 m behind the lens.

Describe the image.

10. Compare the images you've obtained. What conclusions do you draw?

11. What is the difference between placing the apertures in front of or behind the lens? And what is the relation between the diameter of each aperture and its distance from the lens?

Results:

Describe the experimental process you have developed.

Based on your results and the aim of this experiment, discuss the function of diaphragms in optical systems.

EXPERIMENT NO. 22.

Title:

Introducing photometry. Intensity and brightness.

Aim:

Students will become acquainted with the basic concepts of photometry, such as the intensity of luminous sources and the brightness of an image by means of qualitative observation. The variation law 1/r2 will be demonstrated qualitatively.

Equipment:

Optical table; light source; diaphragm; object.

Process:

1. Estimate the distance between the front aperture, and the electrical filament of the light bulb in the light source.
2. Place the 0.005 m diameter aperture at the front slit of the light source.
3. Place the object in front of the aperture at a similar distance to the one estimated in step one.
4. Observe the circular image on the object. Measure the diameter and observe its brightness carefully. Comment on it.
5. Place the object in front of the aperture, but this time the distance should be twice as much as before.
6. Observe the circular image on the object. Measure the diameter, observe its brightness carefully, and compare it to the brightness of the circle in step 4.
7. Place the object a little further from the aperture at a distance three times greater than the distance estimated in step one.

8. Observe the circular image on the object. Measure the diameter and observe its brightness carefully.

9. Compare the diameter and the brightness of the circular images in each of the three situations, where the only element that has changed is the position of the object.

What relation do you think there is between the amount of light that falls upon the object and distance from the light source? Discuss this with your classmates and your teacher.

Repeat this experiment using a bulb of a different voltage. Compare the results.

Plan and carry out several experiments in order to check the accuracy of your conclusions if you think it's necessary!

EXPERIMENT NO. 23.

Title:

Diffraction.

Aim:

Students will be presented with the characterization of light and its generation.

Equipment:

Optical table; light source; laser pointer; lens A; diffraction grating; colour filters; tape-measure or metre stick; white object.

Procedure:

Like the prism, a diffraction grating is capable of separating light into a band of different colours called a spectrum when light shines through it. It looks like a normal piece of plastic, but has thousands of parallel grooves lined up on the surface. These grooves are so thin and so close together that you will need a magnifying glass to see them!

Hold the diffraction grating close to your eye, and look at a small light source through it. Remember: YOU SHOULD NEVER LOOK AT THE SUN! Darken the room a little so you can see the results more clearly, and move the grating up and down. If at first you don't succeed, try again... You know it's worth it!

1) You can use other types of light sources (neon/fluorescent lamps,...) like when you replaced the prism with the grating.

2) See if every colour is present in the spectrum.

USING FILTERS

Only a few colours can go through each filter:

a) Place one of the colour filters in front of the diffraction grating.

b) Look at the light source through the grating you used at the beginning and observe the spectrum.

c) Change the position of the filter, that is, place it behind the grating.

3) Make two lists: one with the colours you observed through the filter, and another with the colours you couldn't see because the filter blocked them.

4) See what happens when you use other filters.

Comment on the work you have done.

EXPERIMENT NO. 24.

Title:

Polarization.

Aim:

Introduction to the concept of polarized light.

Equipment:

Optical table; light source; two polarizers (grey plastic squares); plastic film.

Procedure

The polarizers seem to be plain pieces of plastic. However...
Try to find a few bright objects (never look directly at light sources, particularly at the sun or the laser slit!)
Hold the polarizer close to your eye, and turn it as you observe the bright objects.

1) Describe the things you see. Do you notice anything in particular?

This time you will observe the objects using two polarizers.
Place the second polarizer on top of the first like a sandwich, and use it to observe a well-lit object as you turn one of the polarizers.

2) Describe what you see.
3) Adjust the polarizers so that you can't see through them, and place a plastic film (tightly stretched) between them.

Describe what you see.

Try to stretch the plastic in different directions. You can even make a hole in it using an object that is not very sharp.
I bet you're having fun! (Jelly can be a great light polarizer too, and you can use it to obtain some fun effects!).

Light polarization has many practical applications. For instance, place a polarizer on the screen of your calculator (or on a digital watch with a liquid crystal display). Turn it on and choose a few numbers. Turn the polarizer and see what happens...

EXPERIMENT NO. 25.

Title:

Holograms. Three-dimensional images.

Aim:

Introduction to the concept of the three-dimensional image based on the observation of a hologram.

Equipment:

Hologram; optical table; light source (flashlight).

Procedure

1. After taking a good look at your hologram place it on the optical table.
2. Shine the light source on it.
3. Tilt the hologram to different angles until you are able to see what has been recorded on it.

1) What did you see?
2) What happens if you change the angle of observation?
3) What is the difference between a hologram and a normal photograph?
4) In which situations do you think this type of "photography" could be more useful?

EXPERIMENT NO. 26.

Title:

Optical Fibres.

Aim:

A brief introduction to optical fibres.

Equipment:

Optical fibres; Optical table; light source; laser pointer; lens A.

Procedure:

OBSERVING THE FIBRE

Optical fibres are mostly made of glass.

a) Try to bend the fibre (do it carefully so that it doesn't break!)
What is the difference between the optical fibre and a normal piece of glass?

b) Use a magnifying glass to examine the ends of the fibre carefully.
Draw what the end looks like, and indicate which part you believe to be made of glass.

SHINING LIGHT THROUGH THE FIBRE

Shine a light source directly at the end of the fibre and observe the other end.

c) Try to bend the fibre. Does light appear to be coming out the other end?

Place a pencil between the light source and the end of the fibre, and move it a little.

d) Ask one of your classmates to look at the other end, and figure out if s/he notices the pencil moving in and out of position.

You can send him/her a coded message.

EXPERIMENT NO. 27.

Title:

Introduction to Optical Fibres...

Aim:

A brief introduction to optical fibres and to wave guidance.

Equipment:

Light source; jelly; laser pointer; water tank.

Procedure:

Guiding light...

You know that it's very simple to illuminate a distant object. All you need to do is to shine a flashlight directly at the object, and away you go!
Unless there is an obstacle in between, which might make things a little more complicated.

Move the flashlight and try to let the light pass through the obstacle (in spite of its stubbornness in travelling in a straight line!). Unfortunately that's not always possible! What should you do? Give up? Absolutely not!

Let's get to work! A set of mirrors placed in a strategic position will lead light around the obstacle, and your problem will be solved!

However, if there are several obstacles in between you might have a real problem! Well, no gain without pain! With a few more mirrors and a little patience you will be able to guide the light to the object!

Well... it might be a little more difficult to find a set of mirrors than to have patience. You'll have to find a way. After all, it's the third millennium!

And there is a way: well-known optical fibres. The ones used in the new telephone lines, cable television, and broadband Internet access!
You'll look for them now!

It's a long, hard journey so you'll need some energy for starters!

One or two of those magic packets, a glass of hot water and a square cake tin, and in a minute (or almost) you will be able to make delicious jelly! I'd rather have pineapple-flavoured jelly, but to please everyone let's have tutti-frutti! Since sometimes we need to make sacrifices in the sake of science, and a special treat once in a while won't do any harm, let's treble the amount of jelly powder! It'll be more solid, the kind that doesn't melt in your hand and looks like gum (hmmm...!)

Solid science!

Well... while we wait for the jelly to cool and solidify let's do a few experiments.

Fill the transparent tank half with water, and hold the flashlight (the laser pointer would be better, but be very careful, lasers can be dangerous. Never look directly at the laser slit, or aim the laser at the eyes of your classmates! You could blind them!).

Shine the flashlight (or the laser, which is much thinner and more visible) directly at the water from above.

What happens when the light enters the water?

Now move the light beam a little and see what happens.

Shine the laser on the bottom or on the side of the container from below so that it emerges from the water (be very careful with your eyes!!). Do you see the light beams emerging from the water into the air above? What else do you see?

Incline the laser slowly and gradually. What happens? At a certain point... where has the emerging beam gone?

It seems as though the surface of separation between the water and the air worked as a mirror!

Can you believe that this explains the functioning of light guides and optical fibres? It's called "Total reflection phenomenon" or "Total internal reflection phenomenon"!

Well... let's go back to the jelly!

Carefully cut a few long, thin strips of jelly (2 to 5 cm wide). Hold a strip and shine the flashlight slightly inclined directly at the end of the strip.
What do you see? Where does the light emerge from?

Replace the flashlight with the laser pointer. The path of the light is now much clearer! Draw a diagram that represents the laser, the strip of jelly and the light beam.

Now move the laser a little and observe how it travels inside the strip.

If you incline the laser more than you should, the light will emerge from one side instead of emerging from the end of the strip as it was supposed to. At that point, the inclination of the laser beam in relation to the internal side of the strip is not enough to allow total reflection, and the light emerges!

Well, it's time for brunch now! But you can still have fun if you want to! For example, add another strip of jelly to the end of the fibre. Light will pass from one strip to the other...

Well, use your imagination and have fun!

EXPERIMENT NO. 28

Title:

A few properties of optical fibres and waveguides.

Aim:

The transmission of light through a hard yet bent cylindrical light guide. The transmission of intensity and colour. Loss of light through the sides. Modern fibres: the core and the cladding layer (and its special features).

Equipment:

Flashlight; 3 mm diameter acrylic rod; cards and cellophane papers of different colours; alcohol lamp or Bunsen burner*; Cloth or gloves for protection*; water container*; 2 mm diameter optical fibre (0.5 m long).

Procedure:

1.

Take the acrylic rod and hold one of the ends close to your eye (not too close so you don't get hurt. In fact, 20 or 25 cm is more than enough!). Aim the other end at a light source (a bulb on the ceiling, a window... REMEMBER: NEVER look directly at the sun! You should pick another light source).

Bring the rod near the page of a book (at a distance of a few millimetres) and move it over the characters. Now, aim it at the coloured cards or place the cellophane papers in front of it.
Write down everything you see, and indicate the most interesting results.

2.

Darken the room where you're working.

2.a) Turn on the flashlight and shine it on an object (paper sheet, wall...) at a distance of about 20 cm. Observe the (circular) image that appears. Write down everything you observe (diameter, brightness, ...).

2.b) Connect the acrylic rod to the plastic mortise at the end of the flashlight. Observe the light that emerges from the other end of the rod. Hold the flashlight, and place the rod at a distance of about 20 cm from the object. Write down the things you see.

Compare the results with what you observed before, connecting the rod to the plastic mortise.

2.c) Approach the rod to the object, and see how the size of the image gradually changes.

2.d) Make sure the rod is aimed at the object, and hold it with your other hand, so that your palm clutches the largest possible area of the rod. What do you observe?

3.

Remove the rod from the flashlight. With the help of an alcohol lamp (you should be very careful when you do this, you don't want to get hurt!), bend the rod into a U shape. Hold it by the ends (you should wear gloves or cloths for protection) and bring it near the flame. Slowly move the rod around so that the central 10 cm warm up evenly. When you feel that this area is becoming flexible, take it away from the flame, and quickly bend it into a U shape. After that wait a few minutes until it cools.

3.a) Connect an end of the rod to the flashlight, and turn the flashlight on. Observe the light that emerges from the other end of the rod, and compare what you see with what happened before bending the rod.

3.b) Fill the water container, and gradually sink the curved area of the rod a little deeper.
Do you notice anything different about the amount of light of the emerging beam? (Does this experiment remind you of anything similar?)
Observe the place where the curved area of the rod sunk. Do you see anything interesting? What conclusions do you draw?

4.
Hold the 2 mm diameter and 0.5 m long optical fibre. Connect the fibre to the mortise at the end of the flashlight, and repeat the process undertaken with the acrylic rod: observe the emerging beam, shine it on an object, hold an area of the rod with your hand closed, and, last but not least, sink it under the water, but leave an end outside (this fibre is far more flexible than the rod!)
What's changed in relation to the acrylic rod?

What is the difference between the optical fibre and the acrylic rod?

EXPERIMENT NO. 29

Title:

A few mechanical properties of optical fibres.

Aim:

Students will examine the resistance and flexibility of coated and uncoated optical fibres. A few precautions to take when working with optical fibres.

Equipment:

Flashlight; uncoated optical fibre (transparent); coated optical fibre (1 m long); water container*; knife*; hammer*.

Procedure:

1.

The optical fibre used in the former experiment consists of a core, through which most of the light is transmitted, and is coated with a protection clad which is also transparent and optically less dense than the core. However, protection from propagation of light is not the only requirement

1.a) Hold the end of the uncoated fibre, and remove a piece of the clad with the knife (beware of accidents! You hardly need to do anything. It will be enough if you simply scrape it against a cement floor.) Connect the fibre to the flashlight. What do you see? (don't forget to darken the room!). Something similar happens if you hit the fibre with the hammer, or if you bend it hardly.

2.

The use of an overlay for mechanical and environmental protection of the fibre is very important, and provides greater flexibility and resistance than electric copper wire.

2.a) Place the flashlight close to one end of the fibre (black coating) and turn it on. Roll the fibre tightly into a 4 or 5 cm diameter circle, and then roll it in the other direction. Observe the intensity of the light at the end of the fibre. You can even roll a piece of the fibre around a pencil!

2.b) Place the fibre under water.

2.c) Place the fibre on the table and hit it against the table a few times (but not too hard!).

2.d) Bend the fibre several times vigorously around its centre.

2.e) Remove the fibre from the flashlight. Hold both ends of the fibre, and stretch it as much as you can to try to break it. Connect the fibre to the flashlight again.

What conclusions do you draw?

EXPERIMENT NO. 30

Title:

The preparation of optical fibres. Cutting and polishing.

Aim:

Students will learn to prepare optical fibres to achieve the best results.

Equipment:

Acrylic rod; 1 mm diameter optical fibre with black coating (1 m long); sandpaper nr. 800, nr. 1000, nr. 1200; pliers*; knife or sharp blade*; paper towels*; water container*.

Procedure:

1.

Use the pliers to cut 3 to 4 centimetres off the end of the acrylic rod. Pass the small piece you cut over this text.

What do you think?

Observe the top of the acrylic tube you have just cut. The surface is very irregular, and needs to be polished before being used again.

Take the sandpaper nr. 800, and wet it. Hold the tube perpendicular to the sandpaper. Start polishing with an eight-shape (large) movement. Repeat the movement continuously (10 to 15 times should be enough), and keep the tube vertical. Remove the powder with a little water, and check if the uneven parts have already been eliminated. Repeat the process using sandpapers nr. 1000, nr. 1200, and then using the pink one. If you have been careful and patient enough, you will have a smooth surface, and now as you move the acrylic tube over the text you will achieve better results!

2.

Focus on the optical fibre now. The process is similar to the previous one, but this time it will be better to use a knife or a sharp blade instead of the pliers. Place the fibre on a hard surface (granite, metal...). Carefully hold the blade perpendicular to the fibre. Hold it firmly, cut the fibre at one stroke, and repeat the process from part 1 to polish the fibre.

You have noticed that the optical fibre itself is only the central glass 1 mm diameter piece. The black coating, also known as a buffer works to protect the fibre, and must often be removed. And that is a difficult process! The thing is, you need to remove it without "harming" the fibre. If the side is scratched, the light will escape instead of emerging from the end of the fibre as it was supposed to!

EXPERIMENT NO. 31

Title:

The generation of optical special effects using optical fibres.

Aim:

Students will learn to create some interesting visual effects by slightly altering the optical fibre.

Equipment:

Flashlight; optical fibre (1 m long); cards and cellophane papers of different colours; alcohol lamp or Bunsen burner or soldering iron*; knife or sharp blade*; cloth or gloves for protection*; hair dryer*; aluminium paper*; silicone glue*.

Procedure:

1.

Light the alcohol lamp, and slowly and very carefully bring the end of the fibre near it. You should place the fibre horizontally, and when you notice that the end is starting to melt, hold it vertically (yet still near the heat source) for a few moments. Move it away and slowly turn the end upwards as you roll the fibre between your fingers.

A small ball will be formed at the end of the fibre.

Connect the other end to the flashlight and observe how the light emerges from the first end.

2.

Cut 4 cm off the end of the fibre you have prepared, and keep that piece after polishing the end of the fibre.

Cut the small piece of fibre again near the end, but this time you should do it with a 45º inclination (don't forget: you should cut it vertically and at one stroke).
Observe how the light emerges from that end now.

3.
Roll twenty or thirty centimetres of the fibre around a small tube (a large pen will do). Now, warm it up evenly for about a minute with the hair dryer. Turn off the hair dryer, and wait until the fibre cools. As you remove the tube, you will see that the fibre is still rolled up.
Connect the fibre to the flashlight and see that some light escapes through the side.

4.
Make small (superficial) cuts on the side of the fibre using a knife or a blade. You will see that more light comes out from each hole. With this technique, you can obtain very interesting decorative effects (for instance, if you want to create a light line, all you have to do is make a scratch along the fibre).

5.
On the other end of the fibre, place a flat piece of aluminium paper (use transparent glue, like silicone glue for instance). Wait until it dries.
Observe the light that emerges from the side now.
Can you tell the differences from what happened in step number 4?

6.
Like you did in step number 3, you can use the hairdryer to mould the fibre into anything you like. You just need to make good use of the decorative effect that the emerging light provides.

EXPERIMENT NO. 32

Title:

Scintillating fibres.

Aim:

Students learn about scintillating waveguides, and the generation of light inside the fibre.

Equipment:

Flashlight; several scintillating fibres; opaque cloth or aluminium paper*.

Procedure:

1.
Hold the scintillating fibres.
Observe them carefully, and try to explain how they work.

2.
Cover the side of the fibres completely. Aim one end at a light source and observe the other end.

3.
Uncover the fibre. Cover one end and observe the second one.
Shine the flashlight on the side of the fibre, and observe the uncovered end.

4.
From what you observed, what conclusions do you draw?

EXPERIMENT NO.33

Title:

Using light to communicate.

Aim:

Students will be presented with a small introduction to fibre-optic telecommunications, and will discuss the issue of information encoding.

Equipment:

1 mm coated fibre; mini laser.

How can you communicate using the light that the LED emits? For example, you could simply suggest that "everything is ok" if the light is off, but that you might need help if the light is on. If your friend (the receiver) is familiar with that code s/he will give you a hand every time s/he sees that the light is on. There are more sophisticated and effective ways of encoding information, but there is one in particular that I am sure you have heard of. It's Morse code. In Morse code, each letter of the alphabet is represented as a sequence of short or long signals. For instance, you can use the SOS signal if you need to call for help. The letter S is represented by a sequence of short signals, and the letter O by three long signals. Thus, if you press switch 3 times quickly, 3 times slowly (just press the switch a little longer) and finally three times quickly again, whoever sees the light being switched on and off (and knows Morse code) will get the message and come to help you.

You can try other words or even create your own code if you want to.

Well, how about if you want to send a message to one of your classmates, but you don't want anyone else to understand it (if no one else knows the code...)? And how about if you want to send a message to a friend in a different room?

Procedure:

1.

Place the optical fibre in front of the LED. Light will emerge from the other end, and will only be visible here!

EXPERIMENT NO. 34

Title:

Converting light into sound...Converting sound into light... An easy sound communication system using optical fibres.

Aim:

The students should see that optical fibres can in fact transport sound.

Equipment:

Sound transmitter/receiver; 1 mm diameter coated optical fibre (2 m).

Procedure:

I am sure you know how a telephone works. That is, you know how the person you talk to over the phone can hear what you say even if there are many miles between you.

You know that the receiver in your telephone has a microphone into which you speak, and a loudspeaker where the sounds you hear are generated. The microphone converts sound (sound energy) into an electrical signal (electrical energy) that is carried by an electrical wire (!) to the telephone of the person you are talking to. At the receiving end, the electrical signal is converted in the loudspeaker into sound again.

Well... why have I put an exclamation mark in the previous paragraph next to "...electrical wire (!)"?

You know that telephone wires are being replaced with fibre-optic cables because of their numerous advantages. (visit the kit website).

But... electrical signals don't propagate through optical fibres! The electrical signals generated in the microphone must first be converted into a light signal (remember the previous experiment) and, before reaching the loudspeaker, they are converted into an electrical signal again.

You will now use a simple communication system using optical fibres and see how it works!

1.

Hold the transmitter. Identify the microphone. Take a brief look at the electronic components, and try to locate the light transmitter (blue part). Press the switch, and this will set off the transmitter (when you release the switch this will shut it down). Stretch your arm out in front of you, and look inside the blue part where the light source is (the LED). Press the switch, and hit the microphone gently with a pencil (the aim is to make a heavy sound near the microphone. You can try other ways...). In the meantime observe the LED.
What do you see?

2.

Hold the receiver. Identify the loudspeaker, the electronic components, and the light detector (photo detector) in a blue capsule. Turn on the receiver by spinning it. You will start to hear some noise. Turn up the volume a little.
Cover the capsule of the photo detector. What happens to what you hear?
Aim the photo detector at the window, and then at the flashlight. Place your hand between the flashlight and the photo detector a few times. Describe the things you see.
Aim the photo detector at the lamp on the ceiling.
Can you explain what you observed (heard...)?

3.

Now place the optical fibre inside the capsule of the LED, and the other end inside the capsule of the photo detector in the receiver.

And there's your fibre-optic communication system, so you can start communicating using... light!

Have fun!