

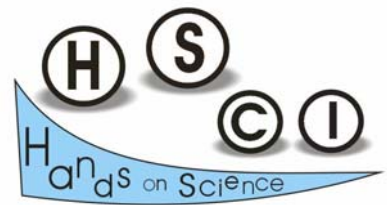
Elementary Optics

Hands-on Training Course



Education and Culture

Socrates
Comenius



The Hands-on Science Network – The AESTIT Comenius 2.1 project

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

EXPLORING OPTICS...

The Light

Light sources.

Look around you.

You see a wide number 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 can predict what would happen ... Everything around you disappears, and the same would happen if you closed your eyes ... No sources of light ... no visual perception!

1. Identify the various 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?

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

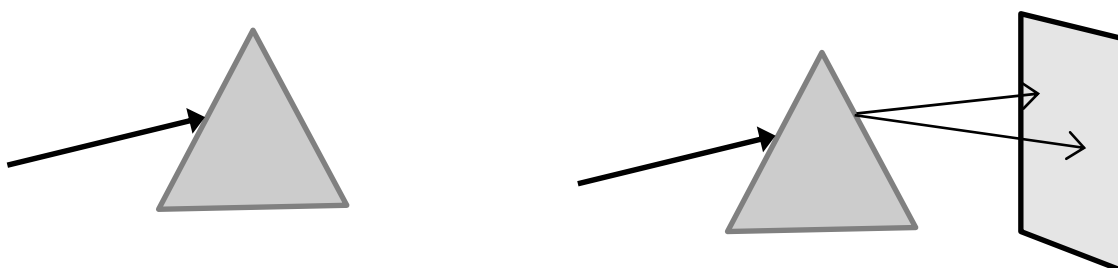
Place a little bit of fluorescein dye in a small glass with water, and shine the flashlight inside the glass. What happened?

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

Dispersion

I'm sure you have already seen a representation of the electromagnetic spectrum in one of your classes. Think about it for a while, and try to recall which wavelengths are associated with the colours of the rainbow.

Shine light from different sources on your prism (the Sun, flashlight, laser – ask your teacher for some advice) as shown below. Aim the spectroscopy at the light source (be careful, don't aim it directly at the sun or the laser beam; instead, use the light reflected by a white piece of paper for instance)



ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

Write down the things you see.

Repeat what you did for the fluorescein by placing several filters in front of the flashlight.
What differences do you see?

What conclusions do you draw?

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

Vision

The human eye.

In previous classes you have observed the anatomy of your eye and the way its most important parts work.

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

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?



ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

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. Change eyes and repeat

Try to represent what you have seen through a simple diagram.

Comment on your work.

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

The visual perception of colours.

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 (better 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 within a narrow range of wavelengths. One of them is particularly sensitive to the wavelengths associated with the blue colour, 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.

Remark: You might have heard that each colour has its own wavelength or that a wavelength is colour. This is not exactly true, and I could give a few examples to prove this. Let's see... A light source with a wavelength of about 590 nm is orange (for instance you can get it when you pass white light through a prism). However, if you mix a yellow and a red light beam you will obtain orange as well. Besides, how would we be able to see that wavelength if the red sensor were sensitive only to the wavelengths associated with red; the green sensor to the ones associated with green...?

Mixing colours.

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 with? a green light?

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

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.

We will now discuss the problem of adding colours' lights.

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 of a light beam are blue, green and red.

Yellow is not one of them! Let's see why.

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 (a white sheet of paper for instance) and the yellow beam shines right next to them. Both images will be yellow, and probably very similar!

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?

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

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

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

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?

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... Do you remember the mixing of paints?...);

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

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

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 (you are used to mix colour inks... not light beams...). Every ink 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 “all” 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?

Remember the 3 colours you got a while ago: $r+g$; $r+b$; $b+g$?

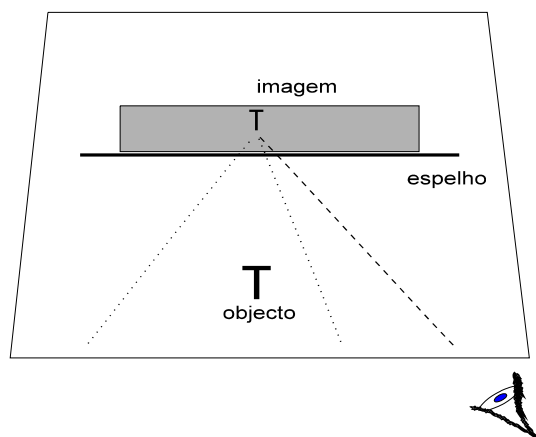
Mix inks of these colours...

... its funny is it not?!

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

Mirrors

The Flat Mirrors



Place a mirror in the middle of a white sheet as shown above, and draw on it a line that represents the position of the mirror.

Place an object (doll, pin...) about 10 cm from the mirror, and place yourself with your eyes leveled with the table (as in the drawing). Observe the image of the object in the mirror.

Where do you think the image is formed?

With the help of a ruler draw a line that represents the direction of the image. (Place the ruler on the paper and aim it in the direction of the image in the mirror)

Move your head a little to see the image from other directions, and write down their directions.

Remove the mirror and extend the lines until they cross. This point is the position of the image!

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

Write down your opinion on this

Hold a pencil vertically over that point, and place the mirror in the correct position. Observe the image again. Write down what you think.

Measure the distance between the object and the mirror _____ and between the image and the mirror _____. Compare them.

Right and left

Face the mirror and try to work out where the right hand of your image is. Why?

Place your head between your legs and face the mirror again (if you stand upside down it will work as well). Are you still confused...?

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

Curved Mirrors

Draw a circle with a 10 cm radius at the centre of a white sheet (preferably A3). Place it on the ray-tracing base.

Hold the bendable mirror on the top of the circle. If you observe it from the bottom of the sheet (centre of curvature) you will have a concave mirror.

Repeat what you did for the flat mirror.

Place the bendable mirror on the bottom of the circle now. If you observe it from the bottom sheet (opposite to the centre of curvature) you will have a convex mirror.

Repeat what you did before with the concave mirror.

What differences do you see in the results obtained? What are the differences between these results and the ones obtained with the flat mirror?

Observe your face in the convex and concave mirrors. What do you see?

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

What happened?

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

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 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 thus 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 (the so called diopter - the surface of separation between two media with different refractive indices), draw a line perpendicular to the side of the glass block (this line segment is called the normal – normal to the diopter). 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 _____(approaches/deviates) the normal, which is perpendicular to the diopters. 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?)

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

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

It's the refracted beam that reaches 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 have been deviate once it passed the surface of separation between the water and the air. Therefore, the coin seems to have emerged!

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

Ray tracing

In this experiment you will repeat the previous experimental process, but you will use different pieces of equipment (optical components) – mirror, prism and lens.

Shine the laser beam collaterally and close to the ray-tracing base (you can place a piece of paper on it if you want to) onto one of the sides of the piece you are working with (a red line will appear over the paper).

The light will be reflected or refracted depending on the piece you use. Draw the position of the piece and the beams you see on the paper sheet. Repeat this process for the different pieces you use.

Write down the most interesting things you see.

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

Lenses

You will work with the ray-tracing base for a little longer.

Place, side by side, a concave and a convex lens on a sheet of millimetre paper, and draw their positions. Hold the laser so that you can see the beam clearly on the paper sheet as shown in the image. Draw the incident and emerging beams. Move the paper sheet laterally (in the direction of the arrow) 1 mm.

Draw the new position of the incident and refracted beams (the one that emerges from the lens) and repeat this process until you have scanned both lenses.

You have obtained a series of parallel beams shining on the lenses. What happened to the emerging beams? What is the difference between the effects of both lenses?

The beams that emerge from the double convex lens will cross at a point (in fact a small area) in front of the lens, called the focal point of the lens. The distance from the centre of the lens to the focal point is called the focal length and measures the power of the lens. The power of the lens in dioptres (I'm sure you've heard this word before if you wear glasses) equals the inverse of the focal length (expressed in metres – which is in fact the correct unit of measurement for distances). Therefore, the shorter the focal length is, the greater will the power of the lens be.

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

The beams that emerge from the double concave lens will diverge, but if you extend them to the other side of the lens you will realize that they will cross on a, say, “virtual point”, the focal point of the lens (remember the images in the curved mirror?)

You will now perform a few experiments using real lenses.

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

The Magnifying Glass

Hold lens A a few centimetres from an “object”, this paper sheet for instance. If necessary focus the image by moving the lens back or forth a little. What do you see?

Use lens B now. What differences do you register?

Try lens C now.

What is the main difference between lenses A and B, and lens C?

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

The projector

Assemble the set up sketched in the diagram represented in the picture, and try to obtain (on the target) a sharp image of the slide (the object) by moving the lens back and forth. Compare the image with the object.

Replace lens A with lens B.

Use lens C now. Can you obtain a sharp image of the object?

Remove the target, and then look at the lens from that output side. What do you think?

(Virtual image!...)

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

The telescope

Hold lens B close to your eye (until it almost touches your eyelashes). With your other hand, hold lens A close to lens B (a few centimetres apart). Close the other eye, and aim the lenses at a distant object (at the end of the room, outside – **never look at the Sun directly!!!**). Move lens A back and forth slightly until the image is focused. Describe it and compare it to the object.

You have just set up a Keplerian telescope. You will now set up a Galilean telescope. Replace lens B with lens C and repeat what you did previously.

Compare the two telescopes.

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

The microscope

Hold lens B close (2 to 3 cm) to an object, 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 "object".

Optical Illusions

Observe the set of cards that have been provided to you, and comment on what you see.

The Hologram

Place the hologram your teacher provided on the optical table, and shine a flashlight on it from different directions.

What do you see?

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

What is the main difference between a normal photograph and a hologram?

Holography is a process used to record and produce three-dimensional objects (images).

Unlike photography, in which you only register the brightness and contrast (and eventually the colour as well) of an object in the film, a hologram registers the brightness, the contrast and the dimension of the object (and perhaps the colour as well)

ELEMENTARY OPTICS *HSCI/AESTIT* TRAINING COURSE

Optical Fibres

As you have learned in class, an optical fibre is made of a very thin glass tube (a few microns), which is surrounded by a similar tube with an inferior refractive index. The light beams that enter the fibre will propagate on the inside through a process called total internal reflection in the (cylindrical) dioptré between the core (interior) and the clad (outer layer) of the fiber.

Observe one of the ends of the optical fibre with the magnifying glass and draw what you see.

Aim the flashlight at one end of the optical fibre, and observe the other end.

Place a pencil between the flashlight and the fibre, and observe the other end. Fix one of the ends of the fibre to the table with some plasticine in front of the flashlight. Bend the fibre several times (not too much... fibers may brake quite easily) and observe the other end. Place colour filters in front of the flashlight.

Comment on these experiments.

With these experiments you were able to study optics *with your own hands*. Enjoy the rest of your time by *playing* a little with the things you learned.

REMEMBER: NEVER LOOK DIRECTLY AT THE SUN OR THE LASER BEAM!

If you have any questions or if you are curious about anything else, let your teacher know.