Notes for teachers

on Module 4

Eye and Vision

Many say that the eye is the window to the soul but for several years people have been trying to open a window into the workings of the eye! It is fascinating how the human eye can help us to see so many things of different shapes, sizes and colours, near and far by adjusting itself in a fraction of a second!
In this module students will compare the parts of a camera with parts of the human eye and learn the function of each part. They will also learn about 'accommodation' – the special property of the eye which helps it to focus on different objects by changing the shape of the lens.

Summary: Students will compare the parts of a camera and the eye. They will also use two lenses to learn about the focusing mechanism in the eye

The module consists of 2 chapters:

- Eye Insight worksheet
- Eye in Focus worksheet

Designed for: lower secondary level (age ca. 12 to 14)

Duration: Each chapter is designed for one lesson of ca. 40 min each;

What students should already know:

- how lenses focus light
- Thin lens formula
- Basic types of lenses

What students will learn:

- To measure focal lengths
- Parts of a camera
- Parts of the human eye
- Function of each part
- Using thin lens formula to work out maximum and minimum focussing distances
- Accommodation in the eye and how it works

Skills your students will foster:

- Teamwork
- Relating tangible concepts (camera) with more abstract ideas (lens in the eye)
- Working with lenses and ray diagrams

This module includes:

- 2 worksheets
- 1 fact sheet

Chapter 1 | Eye Insight

Suggested lesson outline

Students compare the different parts of a camera to those of the human eye and learn the function of each part.

Timing in minutes	**Activity**	**Material**
0-10	General discussion on 'What it means to see'	
10-30	Group work: Solving the 'puzzle' working out the order of parts of the camera and the eye and the functions of each part	WS04.1
30-40	Class discussion on results	
homework	None	

Description of suggested lesson

Please ask your students what they think is the meaning of 'seeing' something. Most of them will probably already know that light from an object enters the eye and allows us to see. Lead them to the understanding that this in itself is not enough for us to be able to see. For instance; we cannot see a chair in the dark and we cannot look directly at the sun. In both cases the amount of light is a problem. So the light has to be 'just right' for us to be able to see and parts of a camera and our eyes are designed to adjust to the light and make it congenial for us to see.

Worksheet "Eye Insight"

Please divide the class into groups of 2-3 students per group. Tell the groups that they should read through the introduction in WS4.1. After this, they can work together on the puzzle. Most of the students will already be familiar with some parts of a camera and some parts of the eye. Please tell the students to share this information within their group (For e.g. shutter, opens and closes therefore allows or blocks the light). Also tell them to think about whether or not the part is fixed, or can move around (this will be easier for the camera compared to the eye and you might need to help them more to understand this aspect about the eye).

In particular students must think about the order in which light passes through the parts of both the eye and the camera and what is happening to the light as it passes through each part. The completed puzzle with the parts in the right order and their function is provided on page 7 for your reference.

Work your way through the groups assisting the students as they need, to come up with the solutions to the puzzle within their groups.

Discussion of results

After all the groups have arranged the different parts in order, ask the students to stick the parts in order into their notebooks and to leave some space to write underneath each part. Then ask them to discuss amongst themselves, the function of each part. Circulate between the groups till you have all the answers. If there is any discrepancy between groups, ask the groups to give reasons for their answers and guide them to the correct understanding.

Ask your students if they are convinced of the following points

1. The eye is an 'optical instrument' which collects the light from an object we look at and detects the image thereby helping us to see.
2. The camera and the human eye are very similar in most respects.

Camera vs. The eye: differences

Ask your students to list some differences between the camera and the eye. Once they have some points per group, note down the different points on the board. Some of them might say that the lens is different; the camera connects to a computer while the eye sends messages to the brain etc. Then, ask them to work together on the second part of question 2) in WS4.1. Lead them to the understanding that the lens in the camera can move back and forth but the lens in the eye is fixed in one position.

If the lens is fixed in one position and the screen (retina) is also fixed – how does the eye clearly see different objects at different distances and of different shapes and sizes?

Leave this point open for the next worksheet and tell the students that in the next lesson they will see how the eye focuses on objects.

For question 3, students should grasp the idea what whilst the eye forms is the 'instrument' for collecting light and sending the information, it is in fact the brain that processes the information into a meaningful image and creates our sense of vision. Much like a computer (whether a processor within the camera or an externally connected device) processes the information to recreate a photograph.

Background information

Receptors in the eye
There are four classes of receptors in the retina of the human eye:
Rods are used to see at night or when there is very low illumination. There are about 120 million rod receptors in the eye and they are very sensitive but not to colour.
Cone receptors are sensitive to colour and there are about 6-7 million cones. These are divided into three categories based on their wavelength sensitivity

1. *L- receptors* are most sensitive to long wavelength light (light which appears as red or variations of red)
2. *M- receptors* are most sensitive to middle wavelengths (light which appears green or variations of green).
3. *S- receptors* are most sensitive to short wavelengths which appear blue to us.

People with normal color vision have L- sensitive, M- sensitive and S- sensitive receptors. People with color variant (sometimes called color defective, or inappropriately called color blind) vision are missing one or more of these receptors.

These receptors are the light sensitive neurons in the eye and they trigger an electrical impulse when light strikes the retina. The image formation on the retina is due to a systematic spatial triggering of these receptors.

The retina compared with a CCD sensor
The way the retina receives images and transmits information to the brain is quite similar to the way a charge coupled device (CCD) sensor works, for instance in a video camera.
In a CCD sensor the pixels are light sensitive. Each pixel is essentially a capacitor and when light strikes it the capacitor develops a charge that is proportional to the intensity of light. This charge is 'coupled' (hence the name CCD) to an external circuit (analogue electronic circuit) through other capacitors and this external circuit emits a sequence of output voltages proportional to the charge. A microprocessor typically converts this sequence back to the intensity of the incoming light based on the voltage.
Digital cameras generally use a "Bayer mask" over the CCD. Each square of four pixels has one filtered red, one blue, and two green (the human eye is more sensitive to green than either red or blue). The result of this is that luminance information is collected at every pixel, but the color resolution is lower than the luminance resolution.
The retina in the eye works in a very similar way. When light is focussed on the receptors in the retina, they get hyperpolarised i.e. their potential (voltage) rises. The resting potential of a neuron is typically about -70 millivolts and this can rise to a maximum of -55 mV. The hyperpolarised receptor (rod or cone depending on the

light) excites a bipolar cell that is right underneath it and the bipolar cell in turn excites the ganglion cell. The ganglion cell transmit the electrical impulse to the brain via the optic nerve. (Please note that this is a simplified version of the actual mechanism which consists of several layers of neurons).

The 'image processing' itself takes place in the brain. More specifically, in the visual cortex which is are the two areas in the back of the brain known as the 'occipital lobes'. The image seen by the right eye is processed in the left side of the brain and vice versa. Although the actual image on the retina is inverted, the image that we 'see' is in fact upright.

Stereoscopic vision

Humans and several other species have *'stereoscopic vision'* which means that they see one object with two eyes, both set in the same plane i.e. in the front of the skull. This is unlike fish for e.g. that have their eyes in the side of their head so they see two different images from each eye. One of the results of stereoscopic vision is depth and position perception. A simple way to test this is to hold your finger is front of your face and focus on something behind your finger. Now alternately shut each eye, rather fast, still focussing on the object. You will sense that the position of your finger moves while the position of the object stays the same. When a person stares at an object, the two eyes converge so that the object appears at the centre of the retina in both eyes. Other objects around the main object appear shifted in relation to the main object (in this case the finger).

The human eye lens and its properties

The lens in our eyes is also known as the *aquula* (Latin, *a little stream*, dim. of *aqua*, *water*) or *crystalline lens*. In humans, the refractive power of the lens in its natural environment is approximately 18 dioptres, roughly one-third of the eye's total power. The refractive index of the human lens varies from about 1.38 – 1.40. The special property of the lens is that it can change its shape, therefore its focal length, and allow us to focus on different objects. Accommodation acts like a reflex, but it can also be consciously controlled. Humans and other mammals as well as birds and reptiles change the optical power by changing the shape of the lens using the *ciliary muscles*. This change can be up to 15 diopters in humans. Fish and amphibians vary the power by changing the distance between a rigid lens and the retina with muscles.

The young human eye can change focus from distance to 7 cm from the eye in 350 milliseconds. This dramatic change in focal power of the eye of approximately 12 diopters (a diopter is 1 divided by the focal length in meters) is achieved by ciliary muscle contraction. The ability to change focus so rapidly declines with age.

Students might ask

How does a digital camera work?

Conventional cameras used film to capture images. Photographic film typically consisted of light-sensitive silver halide. Digital cameras capture images using an array of light sensitive sensors. These sensors are sensitive to the intensity of the incoming light and store the information digitally as red, green, blue colour space or as raw data. There are two main types of sensors; charge-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS). While conventional cameras could function without electricity, digital cameras require a connection to a computer to store and process the images.

Chapter 2 | Focal lengths

Suggested lesson outline

Students learn how the eye focuses light and the principle of 'accommodation'

Timing in minutes	Activity	Material
0-5	Continuation of previous discussion	
10-20	Focal length of the eye experiment	WS04.2
20-30	Class discussion on results	
30-40	Group Work: Focal lengths experiment	Lenses (30 mm and 150 mm focal lengths) LED Module *Not included in kit:* Screen Metre ruler

Description of suggested lesson

Please tell your students that following the discussion in the previous lesson, they will see today how the eye focuses light compared to a camera and also measure the focal lengths of their own eyes.

Focal length of my eye:

Please ask each student to read through question 1) on WS4.2 and work through the experiment in groups of 2-3. When they reach the part where they need to measure the distance between their finger and the eye, they should ask their team member to help with the measurement and vice versa. For the last question ("Is this distance about the same for everyone in the class?) write down the results from each group on the board and ask students to compare. If anyone has a very different result, ask them to share their experiment method and try to see why their answers are different.

The worksheet provides the thin lens formula already in a form such that students can put in the distances and calculate the focal length of their eye.

Once they have completed this part, tell them to work in groups of 2-3 and read through the tasks 2) and 3) on the worksheet. Please ensure that the students fix the screen behind the lens so that the distance is greater than the focal length of the lens (150 mm) and the screen does not move. Once they have measured the first distance, please ensure that they replace the lens with the +30 mm focal length lens and the distance between the screen and lens stays the same.

Discussion of results:

Discuss point 4) with your students, asking them what their results were and what they did. From this experiment can they discuss some qualities of the lens to focus nearby objects and some qualities of the lens to focus far away objects. Most probably they will say that longer focal length focuses far away objects better and vice versa.

Tell your students to look at the lenses carefully and see if they can make some comments about the shape of the lens. They might notice that the 30 mm lens is rounder and the other is flatter. Then ask them what is the other way of focussing on an object, if the lens stays the same and lead them to conclude that there are two ways; either the lens changes or the distance between the lens and screen changes. In the case of the eye only the lens shape can change and this is exactly what happens.

For part 5) students need to use the thin lens formula and understand that the focal length and distance from cornea to retina are both fixed and provided on the previous page. Parts 6) and 7) are optional depending on whether or not you have already covered ray diagrams with your students.

Optional: For parts 6) and 7), allow your students to each draw out an object and a screen (which represents the retina) and first decide where the image is formed for each kind of defect (in front of lens or behind the lens). Then depending on whether the image needs to be brought forward or moved backwards to fall on the screen, they can decide which type of lens would be suitable.

Background information

Liquid lenses

Since accommodation is such a useful process it can greatly improve the compactness and accuracy of devices such as cameras. In the past complex optical instruments always used a combination of lenses which had fixed focal lengths. Extensive research has resulted in the realisation of 'liquid lenses' that can change their shape and focal length on demand. The lens can adapt rapidly and continuously from diverging to converging and be modeled to support all key optical functions, starting with Auto-Focus and Optical Image Stabilization. The technology uses the principle of "Electrowetting" and a combination of transparent and optically defect-free liquids to create a lens and change its characteristics in real time. 'Wetting' is the ability of a liquid to remain in contact with a solid surface and is a combination of various forces. Electrowetting is the modification of the wetting properties of a liquid by applying an electric field to it.

The main advantages of using liquid lenses over glass or plastic lenses are that it allows for a large range of focal lengths, they are robust and more shock resistant that conventional lenses and they can change their focus quickly (in the millisecond time scale). The flexibility of liquid lenses allows the possibility to have several lenses inside a single casing, much smaller in size than current camera lenses.

Liquid lens technology is already breaking into smartphones, cameras and imaging with still a variety of applications to be explored.

Students might ask:

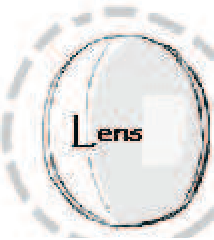
How do contact lenses work?

Contact lenses are usually placed on the cornea of the eye to help correct vision defects. As an alternative to spectacles, the first lenses were made of glass which caused eye irritation and these lenses were unsuitable for use for long periods of time. Glass lenses were replaced by polymethyl methacrylate (PMMA) lenses which were much more convenient but these did not transmit any oxygen through the lens to the cornea. Further research led to the use of rigid gas permeable materials to make contact lenses. However all these lenses were still 'hard' lenses.

The major breakthrough in soft contact lenses came with the the launch of the first soft (hydrogel) lenses in some countries in the 1960s and the approval of the 'Soflens' material (polymacon) by the United States FDA in 1971. Soft lenses are immediately comfortable, while rigid lenses require a period of adaptation before full comfort is achieved. The polymers from which soft lenses are manufactured improved over the next 25 years, primarily in terms of increasing the oxygen permeability by varying the ingredients making up the polymers.

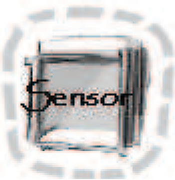
Eye Insight : Puzzle Solution

Houses the lenses and allows them to change their relative distances



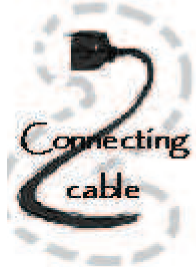
Focusses incoming light onto the sensor

Can open or close to change the amount of light



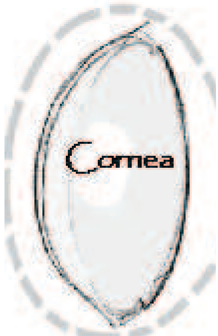
Recieves the light and responds forming the image. Acts like the film

Houses the different parts of the camera and contains the controlling buttons

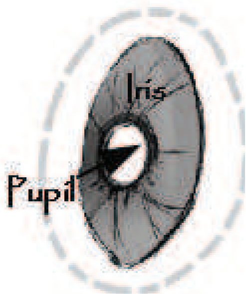


Connects to a computer to allow storage of images

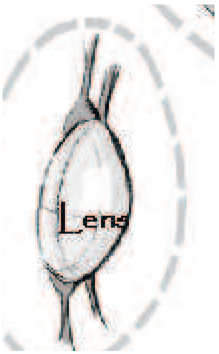
Acts similar to the lens cover to protect the parts of the eye and also acts as a lens

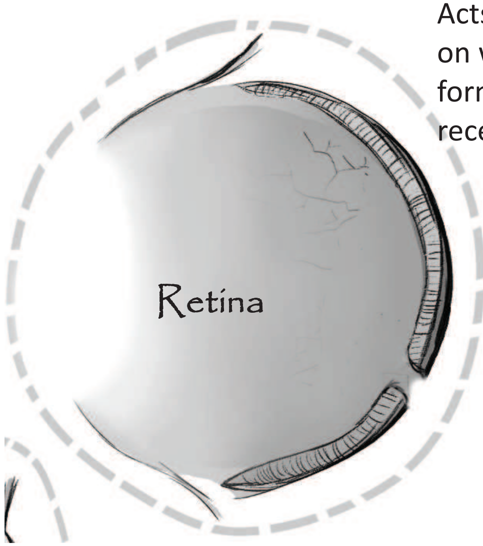


Together act to expand and contract the pupil to control the amoutn of light entering the eye



Focusses incoming light onto the retina





Acts like the screen on which the image forms. It contains receptors

Connects to the brain to transmit the information