Science in Action 8 Textbook **Notes**

Light & Optics

Links: http://www.hazelwood.k12.mo.us/~grichert/sciweb/optics.htm
http://dir.yahoo.com/Science/Physics/Light_and_Optics/
http://camillasenior.homestead.com/optics4.html

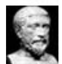
Unit 3 - Light and Optical Systems

1.0 Our knowledge about light and vision comes from explanations, inventions & investigations

1.1 A Challenge of Light (pgs. 176-181) - Timeline History of Views about Light & Astronomy

Ancient Times — [China] [Greece] - used mirrors

 *Archimedes* - planned for the use mirrors in war

 *Pythagoras* - thought light was beams of light coming from our eyes

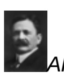
 *Euclid*
- light was reflected
- light travels in straight lines

1st Century —  *Ptolemy* – Light bends when it travels from air to glass

1000 AD (Middle Ages) —  *Al-Haythem* – wrote a book to help explain optics, being the first to accurately describe how vision worked

1670 —  *Isaac Newton* – showed that white light is a mixture of different colors of light

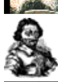
1676 —  *Ole Romer* – determined the speed of light

1920's —  *Albert A. Michelson* – was able to determine more accurately the speed of light

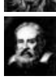
Properties of Light
- Light travels in straight lines
- Light can be reflected
- Light can be bent
- Light is a form of Energy

1.2 Optical Devices (pgs. 182-186) - Timeline History of Optical Instruments

1300 AD —  Alessandra della Spina – wore the 1st pair of eyeglasses

1595 —  Zacharias Jansen – built the 1st microscope 

17th Century 1600 —  Antonie van Leeuenhoek – credited with the discovery of cells using a very simple microscope

 Galileo Galilei – invented the **refracting** telescope

 Isaac Newton invented the **reflecting** telescope

1854 —  Ignatio Porro – prism erecting system (simple binoculars)

1985 — 1st Endoscope used

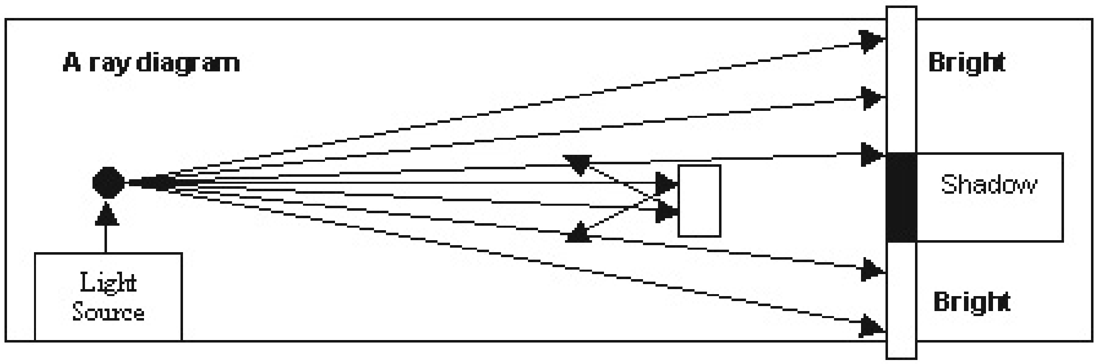
1990 — *Hubble Space Telescope* – named after Edwin Hubble – who's notion of an "expanding" universe formed the basis of **the Big Bang theory** http://hubblesite.org/

2.0 Light behaves in predictable ways.

2.1 Light Travels in Rays and Interacts with Materials (pgs. 188-193)

Ray Diagrams

'Light travels in straight lines.' Because of this principle, the ray model of light can help to explain certain properties of light. A ray is a straight line that represents the path of a beam of light. Ray diagrams can help to demonstrate brightness or intensity of light through changes in distance. The ray model helps to explain how shadows can be formed when an object blocks the ray of light.



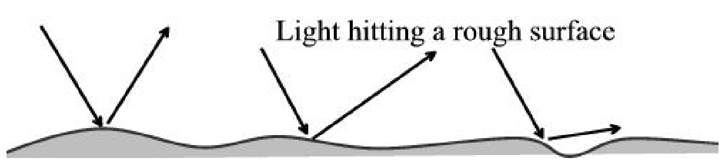
Light Interacts with Materials

Light travels in straight lines until it strikes a surface.
The type of surface the light hits will determine how the light will continue.
If a surface is ***translucent,*** light passes through it but is diffused so that one cannot see clearly the details of whatever is on the other side (a frosted glass window is *translucent*). If a surface is ***transparent,*** light passes through it nearly or wholly undiffused, so that one can see clearly the details of whatever is on the other side (an ordinary glass window is *transparent*). A surface that permits no light to pass through it is ***opaque****;* you can see nothing through it at all (a door is *opaque*).

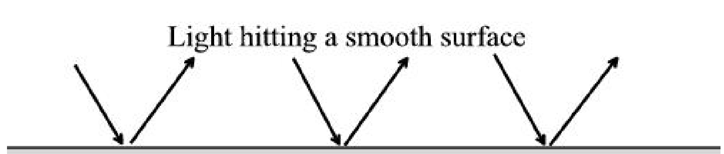
Luminous objects give off light (they are light sources).
Non-luminous objects do not.

Types of Reflection

Diffuse reflection occurs **If light hits a rough or uneven surface, the light is *scattered*.**

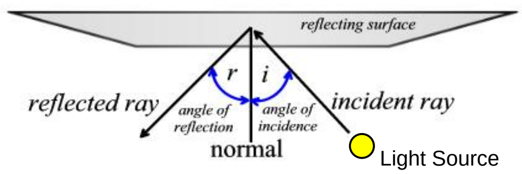


When light hits a smooth surface **regular reflection** occurs, **the light reflects at an opposite angle to the angle it hits.**



2.2 The Law of Reflection (pgs. 194-196)

Reflection is the process in which light strikes a surface and bounces back off that surface. How it bounces off the surface depends on the *Law of Reflection* and the type of surface it hits. Light coming from a light source is called an *incident ray* and the light that bounces off the surface is called a *reflected ray*. A line that is perpendicular (90^o with the surface) to the plane mirror is called the normal line. The angle between the incident ray and the normal line is called the angle of incidence (*i*). The angle between the reflected ray and the normal line is called the angle of reflection (*r*).



The Law of reflection states that:

the angle of incidence equals the angle of reflection

the incident ray, the normal line and the reflected ray all lie in the same **plane** **(an imaginary flat surface)**

Figure 2.12 p. 196

2.3 Reflecting Light with Curved Mirrors (pgs. 197-199)

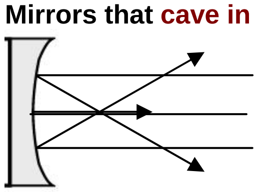
An image is formed in a mirror because light reflects off all points on the object being observed in all directions. The rays that reach your eye appear to be coming from a point behind the mirror. Because your brain knows that light travels in a straight line, it interprets the pattern of light that reaches your eye as an image of an object you are looking at.

This (EXCELLENT) site shows an **animation** of how an image is formed in a mirror.

http://www.glenbrook.k12.il.us/gbssci/phys/Class/refln/u13l2a.html

(Figure 2.13 in the Science in Action Textbook shows how an image in a mirror can be distorted.)

Mirrors that cave in are called Concave mirrors

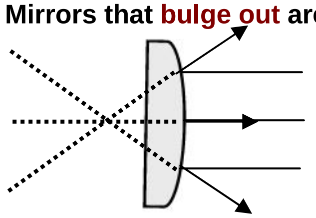


Concave mirrors form an image that appears to be closer than it actually is and can be useful because it can also reflect light from a large area

Focal point is in front of mirror

security devices, flashlights, telescopes, cosmetic mirrors and car headlights

Mirrors that bulge out are called Convex mirrors



Convex mirrors form images that appear much smaller and farther away than the object - but they can reflect light from a large area

Focal point is in behind mirror

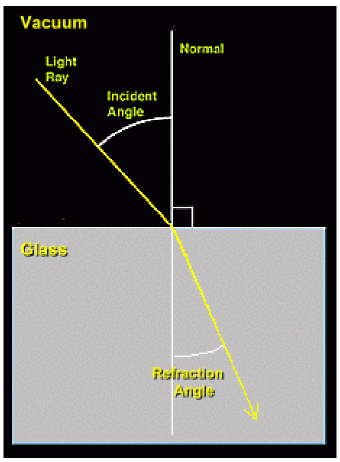
rear-view mirrors and side mirrors on automobiles

2.4 Transparent Substances Refract Light (pgs. 200-203)

Refraction is the process in which light is bent, when it travels from one medium to another. Light bends because it changes speed when it moves through materials that have different densities. The bending of light makes the object's image appear to be in a different position than it really is.

This site shows the angles of how a fish should be caught with a spear.
(VERY Detailed Explanation)
http://www.glenbrook.k12.il.us/gbssci/phys/Class/refln/u13l2a.html

How Light Refracts

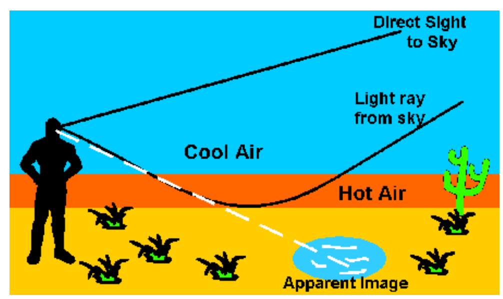


Light travels slower in materials that are denser, because there are more particles.

The ***Law of Refraction*** states that when light travels from one medium, to a more dense medium, the light will be bent ***toward*** the normal, and when it exits the denser medium into a less dense medium it will bend ***away*** from the normal. The new direction of light is called the ***angle of refraction***.

Mirage

Refraction can also occur when light travels through air at different temperatures, because warm air is less dense than cold air. The refraction of light through air is called a *mirage*.



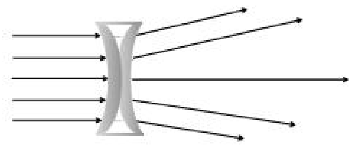
What happens when light strikes a surface?

Type of behavior	What happens to light striking a surface	Nature of surface	What else happens?
Absorption	Energy Transformation	rough, dark, opaque	some light is reflected
Reflection	Bounces off	smooth, shiny	some light is absorbed
Refraction	Travels through in a new direction	different transparent medium	some light is reflected

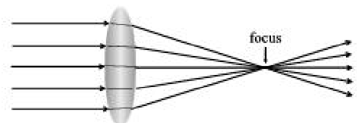
2.5 Lenses Refract and Focus Light (pgs. 204-208)

A **lens** is a curved piece of transparent material (glass/plastic).
When light rays pass through it, the light is refracted, causing the rays to bend.

A **double concave lens** is thinner and flatter in the middle than the edges.
Light passing through the thicker more curved areas of the lens will bend more than light passing through the thinner areas, causing the light to spread out or **diverge**.



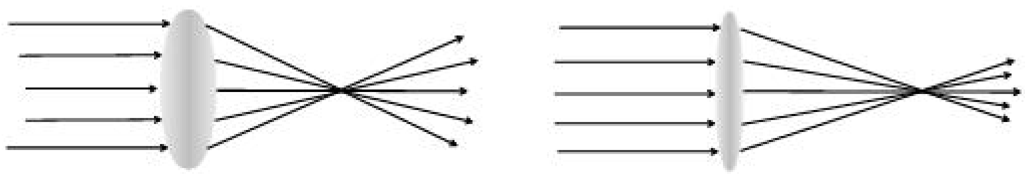
A **double convex lens** is thicker in the middle than around the edges.
This causes the light to come together at a focal point, or **converge**.



Lenses and Mirrors

Lenses are useful optical devices. Eyeglasses, have been made from lenses since the thirteenth century. A convex lens refracts the light rays from an object so they can be focused.

Different size lenses can converge the light rays at different distances, enabling corrections to be made to focal points.



However, light from the left portion of the object is directed to the right and the light from the top is directed to the bottom. This **inverts** the image. Overhead projectors and film projectors do this.

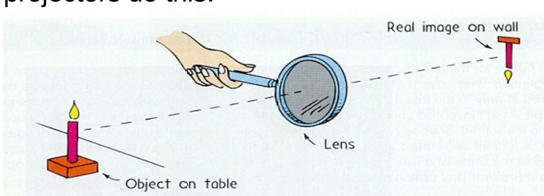
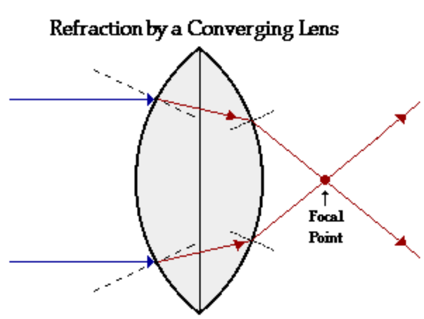
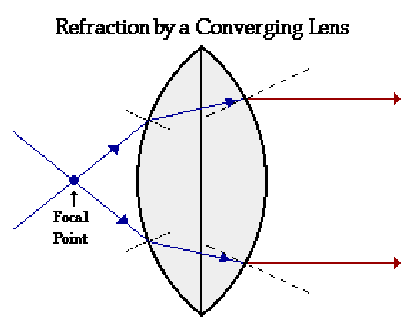


Image Formation With A Convex Lens



Incident rays which travel parallel to the principal axis will refract through the lens and converge to a point.



Incident rays which travel through the focal point will refract trough the lens and travel parallel to the principal axis.

The formation of an image with a double convex lens depends on where the object is placed and the orientation of the light source.

Science in Action 8 Textbook **Notes**

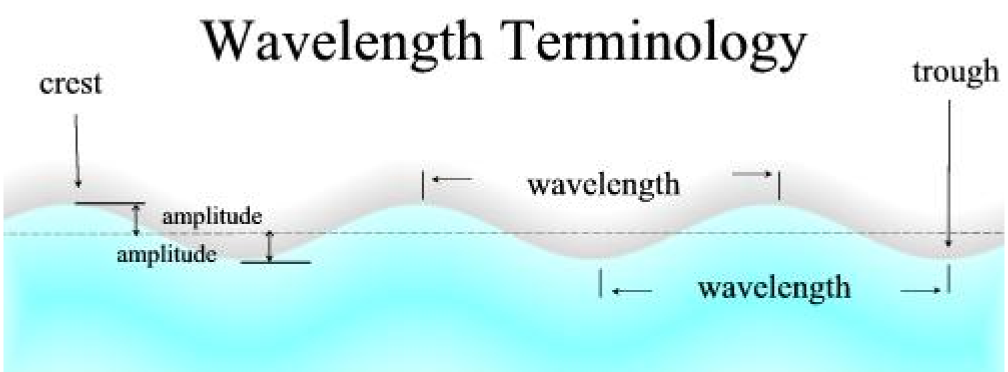
3.0 Light is part of the Electromagnetic Spectrum and travels in waves. (** Extension Material **)

3.1 The Wave Model of Light (pgs. 212-215)

The **wave model of light** pictures light traveling as a **wave**. It doesn't explain everything about how light behaves but it helps us visualize it. Thinking about light traveling in waves helps to explain unpredictable behavior, like when light curves around a opening. When light passes through a small opening, the waves spread out. If the wavelength is short, the waves spread out very little, whereas longer wavelengths spread out more. Wavelength is explored more in the labs for this topic.

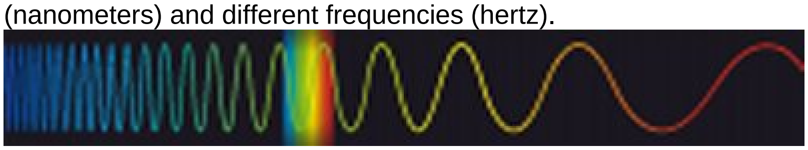
Light Waves In Action
Sunsets can be explained using the wave model of light. As light waves from the sun travel through Earth's atmosphere, they strike particles of different sizes, including dust and other elements. The **longer wavelengths of the reds and oranges** tend to pass around these particles, whereas, the **shorter wavelengths of blue and violet**, strike the particles and reflect and scatter. At sunset, the light we see passes through about 700 kms of the Earth's atmosphere. There are many more particles in the atmosphere at this time of the day, due to the activity going on during the day - so many more blue and violet waves are reflected away. Red and orange are the vibrant colors we see at sunset.

When light passes through a small opening, it spreads out around each side of the opening. To explain this, Dutch scientist Christiaan Huygens (1629-1695) suggested that light travels in a wave, not as a stream of fast moving particles.



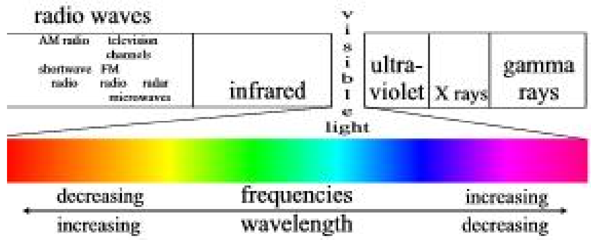
The high parts of the wave are called **crests**. The low parts of the wave are called **troughs**. The distance from crest to crest is called **wavelength** (the distance from one complete crest and one complete trough). The height of the crest or the depth of the trough from rest position is called the **amplitude**. The **Frequency** is the rate at which the crest and the trough move up and down. The number of cycles in a period of time - which is usually measured in **hertz**, or cycles per second.

Different colors on the electromagnetic spectrum have different wavelengths (nanometers) and different frequencies (hertz).



3.2 The Electromagnetic Spectrum (pgs. 216-220)

The sun is the most abundant source of direct natural light on the Earth. There are other forms of energy, invisible, that are also supplied by this source. The tiny band of visible light that we see is only part of the entire spectrum of light energy we receive. Called the electromagnetic spectrum, because the light waves, electrical and magnetic fields vibrate as they radiate to earth.



Applications Of Electromagnetic Radiation

Radiation is a natural part of our environment. Humans have always lived on earth in the presence of radiation. Natural radiation reaches earth from outer space and continuously radiates from the rocks, soil, and water on the earth. Background radiation is that which is naturally and inevitably present in our environment. Levels of this can vary greatly. People living in granite areas or on mineralized sands receive more terrestrial radiation than others, while people living or working at high altitudes receive more cosmic radiation. A lot of our natural exposure is due to radon, a gas, which seeps from the earth's crust and is present in the air we breathe.

Radiation is energy traveling through space. Sunshine is one of the most familiar forms of radiation. It delivers light, heat and suntans. We control its effect on us with sunglasses, shade, air conditioners, hats, clothes and sunscreen. There would be no life on earth without lots of sunlight, but we have increasingly recognized that too much of it on our persons is not a good thing. In fact it may be dangerous. So, we control our exposure to it. Sunshine consists of radiation in a range of wavelengths from long-wave infrared to shorter wavelength ultraviolet. Beyond ultraviolet are higher energy kinds of radiation which arc used in medicine and which we all get in low doses from space, from the air, and from the earth. Collectively we can refer to these kinds of radiation as Ion radiation. It can cause damage to matter, particularly living tissue. At high levels it is therefore dangerous, so it is necessary to control our exposure.

Radio Waves

If you could stretch the infrared wave out even further, so it became a few millimeters long, you could get radio waves. Radio waves are around us all the time. Radio waves have a longer wavelength and a lower frequency than visible light. Different types of radio waves have different uses. Signals from radio and television stations, cell phones and even distant stars pass through your body every day.

Remote Imaging Technologies

LANDSAT is a Canadian satellite that records how different parts of the light from the Sun reflect back to the satellite. It's most important use is for agriculture, monitoring crops for damage by disease, pests and drought.

RADARSAT is a Canadian telecommunications satellite, which, from time to time, sweeps the ground below it with radio waves, penetrating fog, haze, clouds and rain. Their reflection back to the satellite gives scientists information they can use in their studies of the Earth, monitoring ice floes,
search possible sites for minerals, oil and natural gas, monitoring a flood, so that sandbagging efforts can be maximized where it is needed most.

Microwaves have the shortest wavelength and the highest frequency of the all the radio waves.

Microwaves have three characteristics that allow them to be used in cooking:

- they are reflected by metal;
- they pass through glass, paper, plastic, and similar materials;
- they are absorbed by foods.

Microwaves are used to detect speeding cars, to send telephone, satellite and television communications, and to treat muscle soreness. Industries use microwaves to dry and cure plywood, to cure rubber and resins, to raise bread and doughnuts, and to cook potato chips. But the most common consumer use of microwave energy is in microwave ovens. **Microwave ovens** have been regulated since 1971.

Ultraviolet Radiation

Just beyond the violet part of the visible spectrum are wavelengths of about 200 nm., known as ultraviolet (UV) radiation. This radiation is very energetic. It causes tanning, but it can also do irreparable damage to us. *UV rays can damage the cornea of the eye (fogging which can lead to a slow loss of vision)*

In more recent years, more UV radiation is reaching us because the ozone layer in the atmosphere (which protects us from the damaging radiation by absorbing the UV rays) is being thinned. This thinning of the ozone layer is speeded-up by the use of aerosol sprays and Freon gas, which break up the ozone particles.

Infrared Radiation

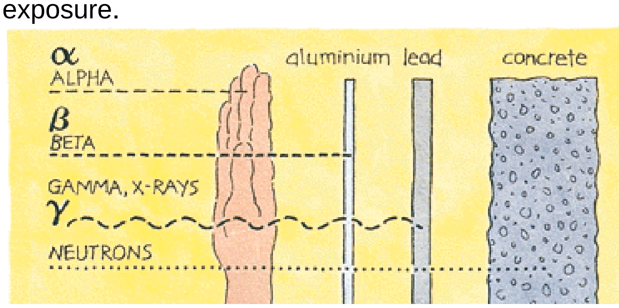
Red light has a wavelength of about 700 nanometers, but it could be stretched out to 100 nm, it would become heat radiation, or infrared radiation. It would become invisible to the eyes, but you could sense it with your skin. Anything that is warmer than its surroundings emit infrared rays.

Practical Applications include:

- motion sensors
- burglar alarms
- heat lamps

X-Rays

Even shorter wavelengths with higher frequencies are the X-rays. These waves pass through tissue (skin and muscle) and are absorbed by the bones. This radiation always stays in the bone and builds up over time. Therefore people who work as technicians taking the x-rays must protect themselves, by leaving the room where the xray is taken and also protect the patient's other areas of the body with lead vests to prevent over-exposure.



Gamma Rays

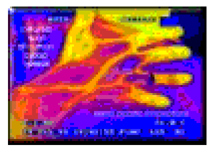
Gamma rays have the shortest wavelength and the highest frequency of all the waves in the electromagnetic spectrum. Gamma rays result from nuclear reactions and can kill cells. This can be useful if the cells being destroyed are harmful - like cancerous cells. The cancerous growth of cells and tissue can be radiated, using gamma rays, and is known as **radiation therapy**.

3.3 Producing Visible Light (pgs. 221-225)

Simply stated, light is the form of energy you can see. This energy can be produced naturally by the sun or fire, or artificially by light-producing technologies, like batteries. Radiation is the wave like transfer of light from its source in all directions. Light is often called **radiant energy**. Light from the sun is formed by nuclear fusion.

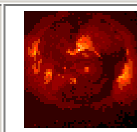
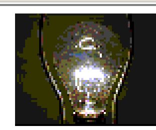
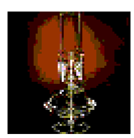
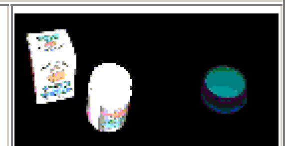
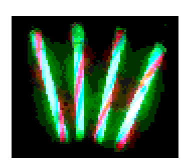
The First Basic Principle of Light

'Light is a form of energy' When light reaches a surface, it can be absorbed and transformed into other types of energy.

… into electrical energy	**… into thermal energy**	**… into chemical energy**
		
Solar cells change light into electricity	**Cameras change light into thermal images**	**Trees convert light energy into food (chemical energy)**

The amount of energy a surface receives depends on the intensity of the light. The more intense the light, the more light can be absorbed.

Sources of Light

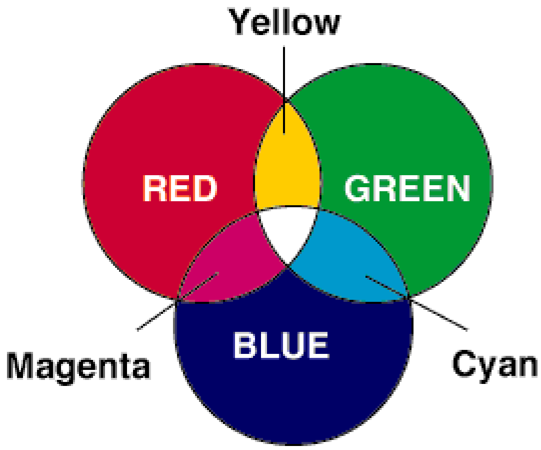
Natural Light Sources		**Artificial Light Sources**	
Sun		**Incandescent** (heat causing a filament of metal to glow - visible light)	
	Electrical energy **---»** Thermal energy **---»** Visible light energy		
Candles or Oil Lamps		**Florescent** (ultraviolet light is absorbed by fabric particles, which in turn emit some of the energy as light - glowing)	
	Ultraviolet light **---»** Energy absorbed **---»** Visible light energy/particles energy		
Wood (fire)		**Phosphorescent** (light energy is stored and released later as visible light)paint	
Bioluminescence(light produced by living organisms)	 firefly light	**Chemiluminescent** (light energy released by chemical reactions)glow sticks Chemiluminescence Movies (Shockwave/Flash)	
UV Light Technologies Light and Color	Chemical energy **---»** Visible light energy		

Other sources of Light Energy can come from the Earth's minerals including: **THERMOLUMINESCENCE** and **TRIBOLUMINESCENCE**

3.4 The Colors of Light (pgs. 226-227) (Color is no longer in the required Curriculum – Extension)

The various colors of the **visible spectrum** have slightly different wavelengths and refract by a slightly different amount.

The **Primary colors** of the visible spectrum are **red**, **green** and **blue**.



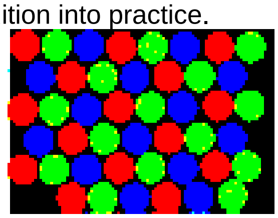
By mixing the correct intensities of the primary colors, you will observe white light.

Secondary colors are cyan, magenta and **yellow**.

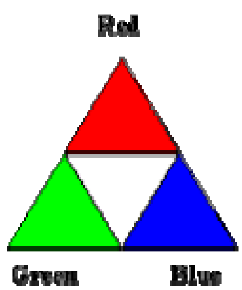
The mixing of three colors of light to produce many different colors of light is called the **theory of color addition**.

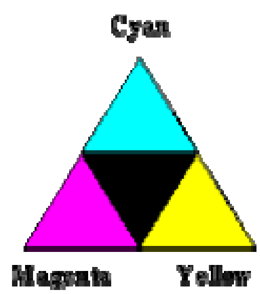
Television

Television puts this theory of color addition into practice.

By changing the brightness of the dots  that make up the screen many different colors can be produced.

The television works by fooling the eye into seeing colors that are not really there.

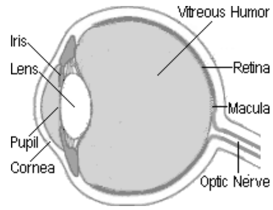




4.0 Eyes and Cameras capture images using the properties of light.

4.1 Image Formation in Eyes and Cameras (pgs. 231-235)

There are many similarities between the human eye and the camera.

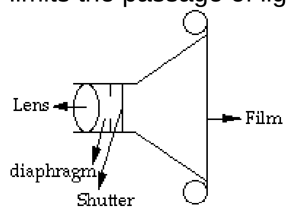


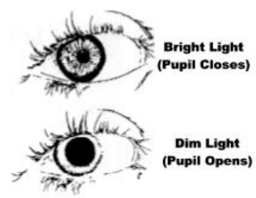
There is also a detailed color image of the eye in Science In Action (Figure 4.1, p. 231)

How Light Gets In
In order to adjust the amount of light that enters the eye and the camera, a special device opens and closes to let just the right amount of light in.

In the eye, the device (or part of the eye) that controls the amount of light entering is called the **iris** (the colored part of the eye), which changes the size of the **pupil** - in much the same way as the **diaphragm** controls the **aperture** (opening) of the camera lens. The natural adjustment in the size of the pupils is called the **iris reflex**, which is extremely rapid. This iris reflex action automatically adjusts the pupil when you go from a darkened area to a well-lit area, or, from a well-lit area to a darkened one.

In the camera, the **diaphragm** controls the **aperture** (opening) of the lens and the **shutter** limits the passage of light.

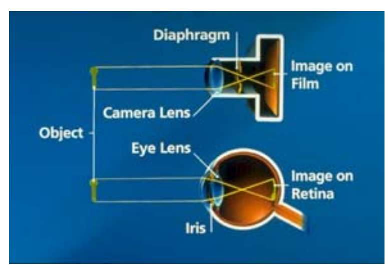




Parts of the Eye
http://www.college-optometrists.org/public/eyeparts.htm

When Light Gets Inside

In the eye, when the **photoreceptor cells** in the retina detect light (**rods** are highly sensitive to light and **cones** detect color), they produce small electrical impulses from the **retina** to the brain, by way of the **optic nerve**. The film at the back of the camera contains light sensitive chemicals, which change when light hits it. These chemicals form the image on the **film**.



The parts of a camera are housed in a rigid lightproof box, whereas layers of tissue hold the different parts of the eye together.

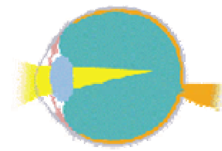
The eyeball contains fluids, called **humours**, which prevent the eyeball from collapsing and refract the light that enters the eye.

Focusing The Light
In a camera, if an object moves closer to the film, the lens must move away to keep the image in focus. In the human eye, the lens cannot move, so the **ciliary muscles** change the shape of the lens (by making the lens bulge in the middle if the image comes closer to you and stretch if the object is further away). This is done so that the eyeball isn't stretched. The process of changing the shape of the lens is called **accommodation.** As people become older, the lens stiffens and loses its' ability to change shape (doesn't bulge) and many people need to wear (convex lens) reading glasses, so that the images can be focused.

Image Formation

The lens in the human eye is a convex lens, which focuses the light rays entering your eye to a point on your retina (a light sensitive area at the back of the eye). The image you see is formed on the retina. Some people however have eyes that are too long or too short.

If their eye is too long, the image forms in front of the retina - this is a condition called **Myopic**, or **near-sightedness** (they have trouble seeing distant objects).



If their eye is too short, the image forms behind the retina. This condition is called **Hyperopia** or **far-sightedness**. (objects that are close to them are difficult to see)

Correcting Vision Problems With Lenses

Knowledge of how light behaves when it travels through **lenses** helps eye specialists correct vision problems. The shortest distance at which an object is in focus is called the ***near point of the eye***. The longest distance is called the ***far point of the eye***. On average, an adult has a near point of about 25 cm, whereas babies have a near point of only 7 cm. The far point is infinite (because you can see the stars).

Laser Eye Surgery

Instead of wearing glasses many people are now opting to have an eye surgeon use a **laser** to correct a vision problem. The surgeon cuts a thin flap of tissue covering the eye, fold it over, then the cornea is reshaped with a laser. The reshaped cornea acts like a corrective lens, allowing the light to be bent so it will properly focus on the retina.
In 1966, Theodore H. Maiman, a physicist at Hughes Aircraft Company in California became the first person to use a process called ...

light **a**mplification by the **s**timulated **e**mmission of **r**adiation

or **laser** light.

Incandescent lights give off many different colors and therefore have many different frequencies and wavelengths. The waves are jumbled and crests from one wavelength might overlap the trough of another, making the waves work against each other. This type of light is **incoherent**. Laser light is quite different. It gives off a single wavelength (frequency) of **coherent** light. Lasers have many useful ***applications***:

- Scanners (bar codes in retail shops are scanned to give the price)
- Digitized data are read by a laser on a compact disk (CD)
- Lasers are use by law enforcement officers to detect the speed of vehicles.
- Laser light can be released in pulses or in a continuous beam. In either form, it is so powerful, that it can make precise cuts through metal and can also be used in surgery, as a scalpel - or, to instantly seal broken blood vessels, because it produces such intense heat.

Night Vision Goggles

In night vision goggles, light is focused onto an image intensifier. Inside the intensifier, the light energy releases a stream of particles, which hit a phosphor-coated screen. These glow green and the person looking in the goggles can view a green image.

Can you find your blind spot?

The point where the retina is attached to the optic nerve does not have any light sensitive cells. This point is known as the **blind spot**.

View this image at arm's length. Cover your right eye with your hand. Stare at **x**, slowly leaning closer to the image, until the dot disappears (when you reach your blind spot) and then reappears when you have passed your blind spot.

4.2 Other Eyes in the Animal Kingdom (pgs. 236-238)

http://www.astc.org/exhibitions/eyes/introeyes.htm

Camera Eyes

Eyes that have a cornea, a lens and a retina are called **camera eyes**. **Vertebrates** (animals with backbones) for the most part have camera eyes.

http://www.ski.org/CWTyler_lab/Eyepage/index.html

Fish have camera eyes with a perfectly round lens, which bulges out from the pupil, allowing it to see in practically every direction.
Birds have sharper vision than humans because they have five types of cones (humans have only 3), each sensitive to different wavelengths of light.
Nocturnal animals have eyes that collect as much light as possible because of their very large pupils. They also have a layer, called *tapetum lucidum*, inside their eye, which acts as a mirror. They also have many more rods than cones in their retina making their eyes more sensitive to low levels of light.

Compound Eyes

Insects and crustaceans have compound eyes. Each eye is made up of many smaller units called **ommatidium**. An ommatidium looks like a long tube with a lens on the outer surface, a focusing cone below it, and then a light sensitive cell below that.
The compound eye is great for spotting movement, but with so many lenses it is difficult to form a single **coherent** image. Instead it forms a **mosaic image** (much like a tv screen).

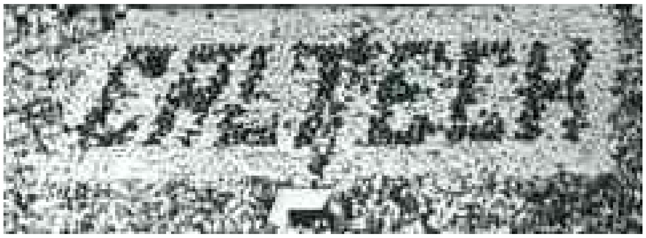
4.3 Image Storage and Transmission (pgs. 239-244)

Most information today is stored **digitally** (converted into numbers).

Stadium Images

The stadium image is made up of people holding different colored cards. Each card is assigned a seat based on the graphic representation of where the colors need to be to produce the correct effect.

This stadium image was one of many designed by college students from Caltech – even though their team was not in the **1961 Rose Bowl** – Read the story of how it stunned the world by clicking on the image



http://www.museumofhoaxes.com/pranks/rosebowl.html

Digital Images

Just as in the stadium image, a big picture made out of small colored squares, a digital image is a picture made up of smaller colored pieces called **pixels** (**pic**ture **el**ements). Each small pixel is assigned a place and is represented by a number. This long series of numbers can then be stored in the memory of a computer to be accessed at a later time.

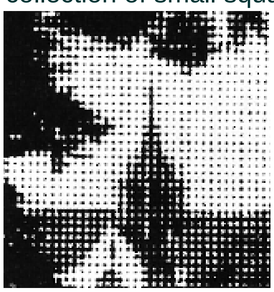
Coloring A Digital image

Once the individual pixels are in the correct order, each pixel is assigned a value, which corresponds to a specific color. When the picture gets reassembled, the computer reads the value of each pixel and makes that pixel the correct color.

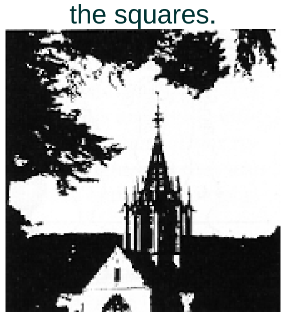
Digital Image Quality

The quality of the digital image depends on the size of the pixels.

If the pixel is large you will see the image as a collection of small squares.



If the pixel is small you will not notice the squares.



The quality of the image is represented by its **resolution**. The more pixels there are in the image, the higher the resolution.

Capturing Digital Images

Scanners, digital video recorders, and digital cameras use a **charge-coupled device** (CCD) to capture the light. The CCD is a grid similar to graph paper. As the light enters each grid square it creates a small electrical charge, which is then converted into digital information and stored on a hard drive, compact disk or digital tape.

Transmitting Digital Images

Digital images can be sent over vast distances, without having to be processed. A powerful computer can convert the digital information very quickly. Digital imaging can also collect different parts of the electromagnetic spectrum, allowing infrared as well as visible images to be captured.