Science Focus 8

Teaching

Notes

Edquest Resources 2001

Topic 1 – What is Light? (pages 176 – 187)

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** (Off the Wall p. 176)

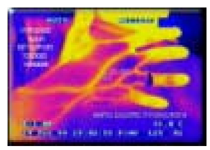
The First Basic Principle of Light

'***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

Solar cells change light into electricity

… into thermal energy



Cameras change light into thermal images

… into chemical energy

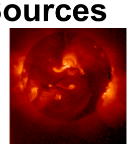
Trees convert light energy into food (chemical energy)

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

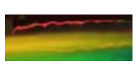
Sun



Candles or Oil Lamps

Wood (fire)

Bioluminescence
(light produced by living organisms)



firefly light

Artificial Light Sources

Incandescent
(heat causing a filament of metal to glow – visible light)

Electrical energy → Thermal energy → Visible light energy

Florescent
(ultraviolet light is absorbed by fabric particles, which in turn emit some of the energy as light – glowing)

Ultraviolet light energy → Energy absorbed by particles → Visible light energy

Phosphorescent
(light energy is stored and released later as visible light)
paint

Chemiluminescent
(light energy released by chemical reactions)
glow sticks

Chemical energy → Visible light energy

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

The Cost of Lighting

Electrical energy costs money to produce. A **watt** is a unit of electrical power. The cost is calculated by how much of the electrical energy is used over a certain period of time. Calculations are made in kW▪h's. 1 kW▪h is 1000 watts of electrical energy operating for 1 hour.

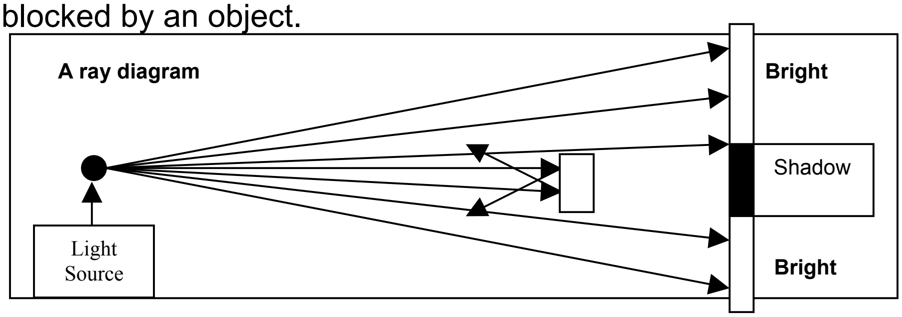
Example: Calculate the cost of leaving a **60W light bulb** on for **10 hours**.

Convert 60**W** to **kW** by dividing by 1000	60 **W** / 1000 = 0.06 **kW**
Calculate the number of **kW hours**	0.06 **kW** x 10 hours = 0.6 **kW▪h**
Calculate the cost by multiplying the number of hours by the cost per **kW▪h**	If the cost per kW▪h is $0.08 The cost of electricity to operate the 60W light bulb for 2 hours would be 0.6 kW▪h x $0.08 = $0.048 (**4.8 cents – or about 5 cents**)

The Ray Model of Light

'Light travels in straight lines'

Because of this principle, the **ray model of light** can help to explain certain properties light. A **ray** is a straight line that represents the path of a beam of light. The ray model helps to explain how **shadows** can be formed, when the ray of light is blocked by an object.



Light travels in straight lines until it strikes a surface.
The type of surface will determine how the light will continue.

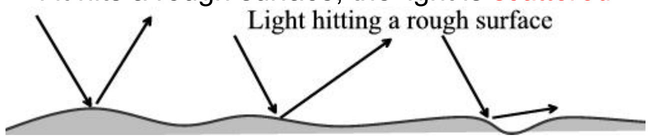
If the surface is **transparent**, the light **continues in a straight path** through the object
If the surface is **translucent**, the light will be **diverted (refracted)** after it passes through
If the surface is **opaque**, the light will be **blocked** and not allowed through the object

Diagram (Figure 3.12 p.185)

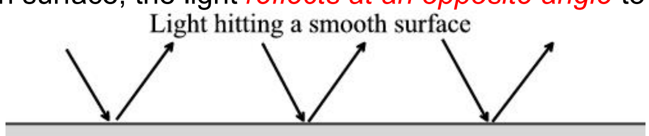
Topic 2 – Reflection (pgs. 188 – 199) (Optics Website)

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.

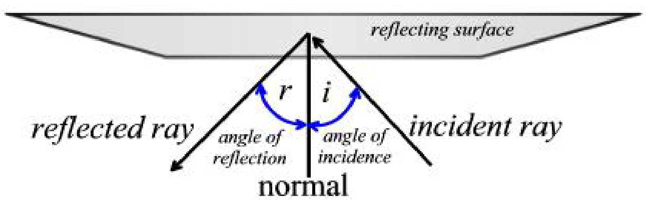
If it hits a rough surface, the light is *scattered*.



If it hits a smooth surface, the light *reflects at an opposite angle* to the angle 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° 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).



Forming An Image

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 lie in the same plane (an imaginary flat surface)

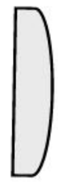
Figure 3.17 p. 194

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.

Figure 3.19 explains why an image in a mirror is the same size as the object and appears to be the same distance from the mirror as the object. (only true for flat mirrors)

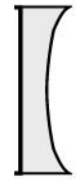
Curved Mirrors

Mirrors that bulge out are called
Convex mirrors



Convex mirrors form images that appear much smaller and farther away than the the object - but they can reflect light from a large area, making them useful as security devices.

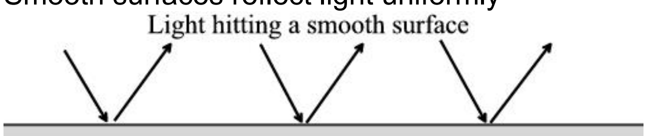
Mirrors that cave in are called
Concave mirrors



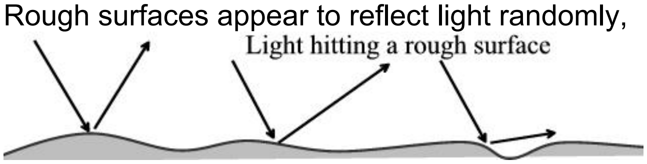
Concave mirrors form an image that appears to be closer than it actually is and can be useful because it can also reflect light from a large area
- side mirrors on automobiles.

Rough Surfaces

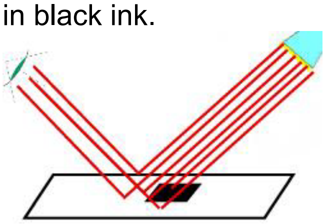
Smooth surfaces reflect light uniformly



Rough surfaces appear to reflect light randomly,



but this seemingly scattered light creates the image of the print on the page.
Light hits the white paper and reflects in all directions (some of it reaching your eye). Since there is no pattern, your eye just sees white light. The ink on the paper absorbs the light and no light from the ink reaches your eye. Therefore your eye sees the letters in black ink.



(see Figure 3.23, p. 198)

Using Reflections

Reflectors help to make bicycles and cars visible at night. A reflector is made up of hundreds of tiny, flat reflecting surfaces arranged at 90o angles to one another. These small surfaces are packed side by side to make the reflector. When light strikes the reflector the light bounces off the tiny surfaces and bounces back toward the light source.
Pool players use the law of reflection to improve their game. Like a light ray, a pool ball travels in a straight line. In a 'bank shot' (Figure 3.25, p. 199) the cue ball is bounced off the cushion at an angle which enables the player to hit the target ball. This angle is calculated as the angle of contact (with the cushion) is equal to the angle of impact (with the target).
Topic 2 Review p. 199

Topic 3 – Refraction (pgs. 200 – 205)

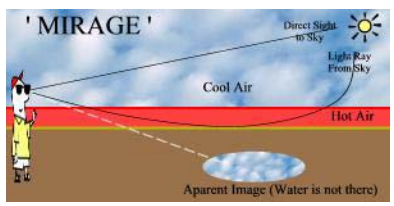
Refraction is the process in which light is bent, when it travels from one medium to another. Light bends because it changes speed when it moves through materials that have different densities. Light travels slower in materials that are more dense, because there are more particles. The bending of light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

Around a Bend with Light

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**.

Image

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.**



The pools of water you see on a hot summer day are often caused by this effect, because the air closer to the ground is hotter than the air above it. As you approach these pools, they disappear - because they were never there.

Is That All There Is To Light?

What happens when light strikes a surface? ......

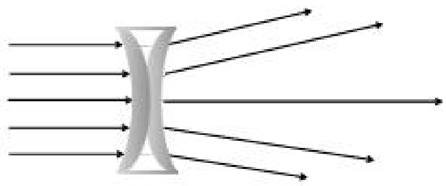
Type of behavior	What happens to light striking a surface	Nature of surface	What else happens?
Absorption	Energy Transformation	rough, dark, opaque	some light is reflected
Reflection	Bounces off	smooth, shiny	some light is absorbed
Refraction	Travels through in a new direction	different transparent medium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

Topic 3 Review p. 206
Wrap-Up (Topics 1-3) p. 207

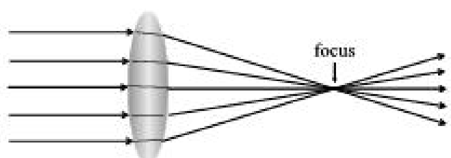
Topic 4 – Lenses and Vision (pgs. 208 – 220)

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**.



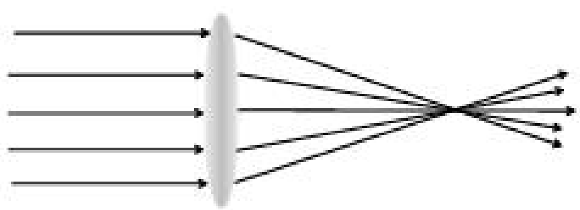
A **double convex lens** is thicker in the middle than around the edges.
This causes the light to come together at a focal point, or **converge**.



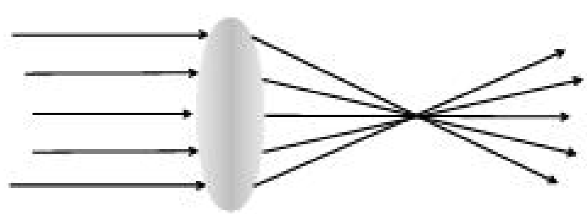
Lenses and Mirrors

Lenses are useful optical devices. Eyeglasses, have been made from lenses since the thirteenth century.

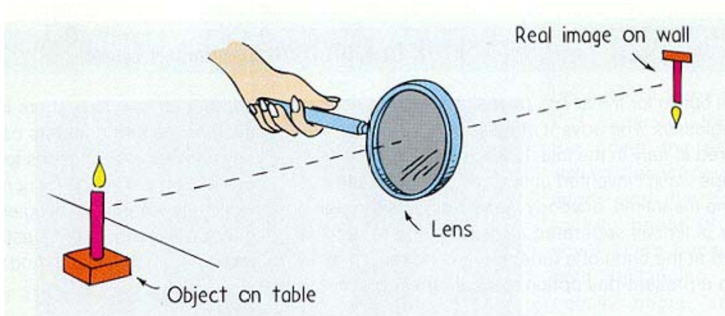
A convex lens refracts the light rays from an object so they can be focused.



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

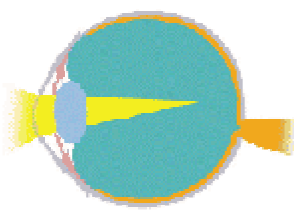


However, light from the left portion of the object is directed to the right and the light from the top is directed to the bottom. This inverts the image. Overhead projectors and film projectors do this.



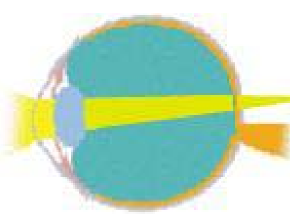
Eye Spy

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, making object that are close to them difficult to see. This condition is called far-sightedness.

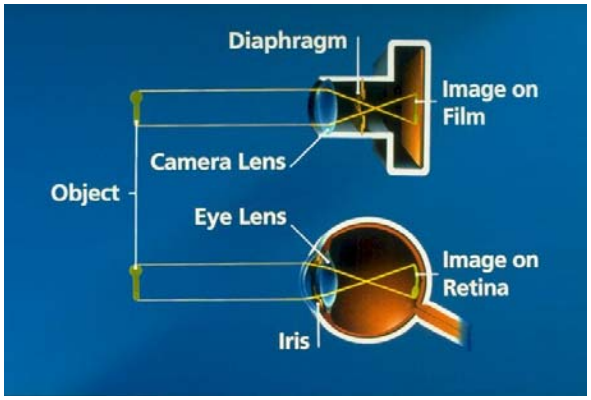


Knowledge of how light behaves when it travels through lenses helps eye specialists correct vision problems.

(**see Figures 3.32A, 3.32B, 3.32C page 210**)

Comparing the Eye and the Camera

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



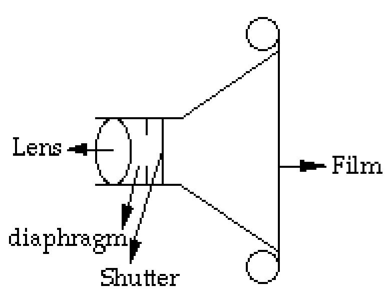
There is a more detailed image in Science Focus (Figure 3.33A, p. 211)

Putting It in Focus

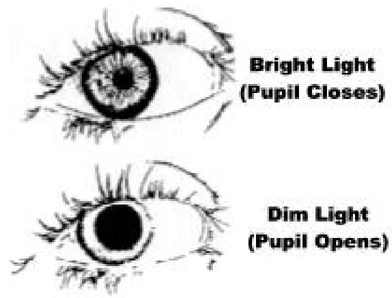
In a camera, if an object moves closer to the film, the lens must move away to keep the image in focus. In the human eye, the lens cannot move, so the **ciliary muscles** change the shape of the lens (by making the lens bulge in the middle if the image comes closer to you and stretch if the object is further away). This is done so that the eyeball isn't stretched. The process of changing the shape of the lens is called **accomodation**. 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.
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).

Bringing In The Light

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



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.

Seeing the Image

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. In the eye, when the cells in the **retina** detect light, they produce small electrical impulses from the retina to the brain by way of the **optic nerve**. 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**.

Can you find your 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**.

The parts of a camera are housed in a rigid light-proof 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.

Topic 4 Review p. 220

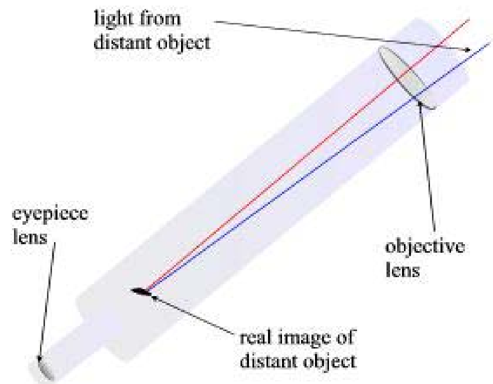
Topic 5 – Extending Human Vision (pgs. 221 – 226)

Tools have been developed, to extend our vision, enabling us to see tiny micro-organisms, far-off distances and the vast reaches of outer space.

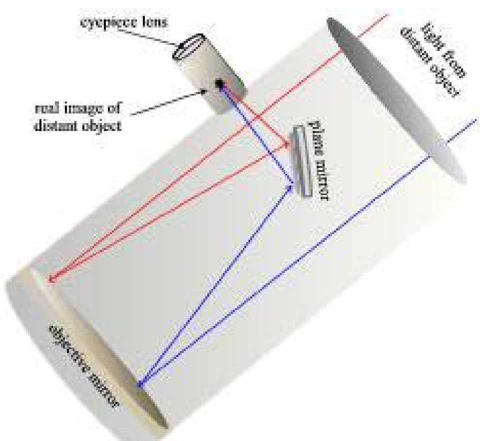
Telescopes

Telescopes help us to see distant objects more clearly.

In a **refracting telescope**, light from a distant object is collected and focused by a convex lens called the objective lens. A second lens, called the eyepiece lens, works as a magnifying glass to enlarge the image.



refracting telescope (Figure 3.41A p. 221)



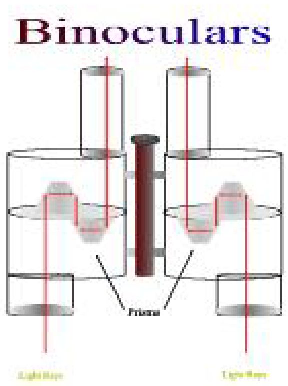
reflecting telescope (Figure 3.41B p. 222)

A **reflecting telescope** uses a concave mirror to collect rays of light from a distant object. This mirror is called the primary, or objective mirror, which forms a real image magnified by the eyepiece lens.

The lens in a refracting telescope and the mirror in a reflecting telescope collect as much light as possible from distant objects. These collectors then focus the light into an image. The further away the image is from the lens, or the mirror, the greater the magnification. For the greatest magnification the telescope needs to have as large a distance as possible between the object being viewed and its image.

Binoculars

Binoculars are actually two reflecting telescopes mounted side by side. In binoculars, the telescopes are shortened by placing prisms inside, which serve as plane mirrors. In this way, the light entering the binoculars can be reflected back and forth inside a short tube.



Microscopes, Telescopes and Scientific Knowledge

A magnifying glass is a very simple microscope, which typically magnifies about 10 times. In 1676, a Dutch scientist, **Anton Van Leeuwenhock** used a simple convex lens to view bacteria (magnified about 280 times).

Compound microscopes (***as you learned in Unit 1***) have an objective lens that forms a real image of the object, which is then magnified by an eyepiece lens. Usually more than one objective and eyepiece lens are used to increase the magnification and improve the sharpness of the image.


Calculate Field of View

New Discoveries

Scientists have learned many new things as a result of the development of microscopes and telescopes. Living tissue is composed of living cells, in which functions and reproduction can be viewed, as well as activity in relation to cancerous growth and destruction by viruses. Scientists can also now study the genetic make-up of cells. Similarly, the improvements in the telescope has opened up the universe for viewing and study. Telescopes and microscopes have their limitations, which reveal the nature of light.

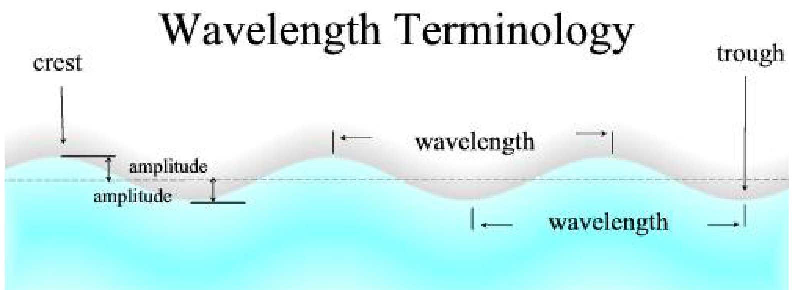
Topic 5 Review p. 226 **Wrap-Up (Topics 4-5) p. 227**

Topic 7 – The Wave Model of Light (pgs. 237 – 248)

Remember that ***light travels in straight lines***. Sir Isaac Newton tried to explain why. He proposed that light beams are made of streams of extremely tiny, fast-moving particles. These tiny particles of light, he suggested, could only travel in straight lines, not around objects.

Looking at Wavelength

After doing the **Find Out Activity** on p. 237, it appears that light is not made up of tiny particles that travel in straight lines as Newton suggests. 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.

The Wave Model of Light

The wave model of light pictures light travelling as a wave. It doesn't explain everything about how light behaves but it helps us visualize it. Thinking about light travelling in waves helps to explain unpredictable behaviour, 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 colours we see at sunset.

See the diagram - Figure 3.59, p. 245 - to visualize this action.

Laser Light

In 1966, Theodore H. Maiman, a physicist at Hughes Aircraft Company in California became the first person to use a process called ...

light
amplification by the
stimulated
emmission of
radiation

or **laser** light.

Incandescent lights give off many different colours 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.

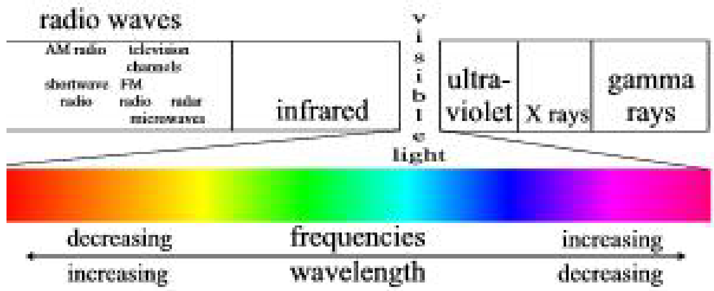
Lasers have many useful applications:

- **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.
- Eye surgeons use lasers to correct vision defects (shaving off areas of the cornea - to correct problems caused by irregularities in the shape of the eyball)
- They can also 'spot weld' a detatched retina
- One day dentists may use lasers to vaporize cavities, instead of drilling into them.

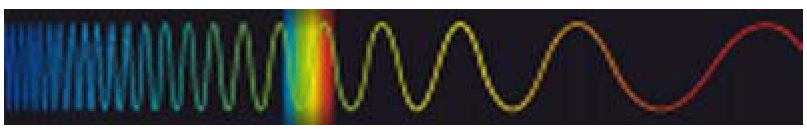
Topic 7 Review p. 248

Topic 8 – Beyond Light (pgs. 249 – 256)

The sun is the most abundant source of direct natural light on the Earth. There are other forms of 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.



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



Radiation in the Environment

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 and Life

Radiation is energy travelling 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 recognised 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 infra-red 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 Ionising 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.

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

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 have a longer wavelength and a lower frequency than visible light. Different types of radio waves have different uses.

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;
- and they are absorbed by foods.

Microwaves are used to detect speeding cars, to send telephone, satellite and television communications, and to treat muscle soreness. Industry uses microwaves to dry and cure plywood, to cure rubber and resins, to raise bread and doughnuts, and to cook potato chips.

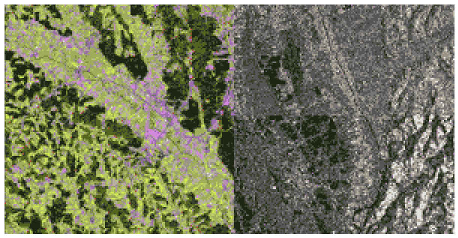
The most common consumer use of microwave energy is in microwave ovens.

Microwave ovens have been regulated since 1971.

Remote Imaging Technologies

Radio waves are around us all the time. The signals from radio stations, television stations, cell phones and even distant stars pass through your body every day.

LANDSAT is another 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 give scientists information they can use in their studies of the Earth.

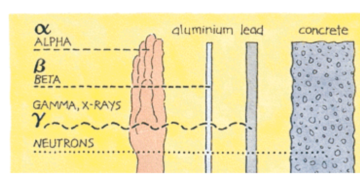
- Monitoring ice floes, which can endanger ships
- Search possible sites for minerals, oil and natural gas.
- Monitoring a flood, so that sandbagging efforts can be maximized where it is needed most.

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 irrepairable 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 aeorsol sprays and Freon gas, which break up the ozone particles. (see Figure 3.70 p. 254)

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**.

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