Light in medicine

Properties of light

Light has some interesting properties, many of which are used in medicine:

1. The speed of light changes when it goes from one material into another. The ratio of the speed of light in a vacuum to its speed in a given material is called the index of refraction. If a light beam meets a new material at an angle other than perpendicular, it bends, or is refracted. This property permits light to be focused and is the reason we can read and see objects clearly.
2. Light behaves both as a wave and as a particle. As a wave it produces interference and diffraction, which are of minor importance in medicine. As a particle it can be absorbed by a single molecule. When a light photon is absorbed its energy is used in various ways. It can cause a chemical change in the molecule that in turn can cause an electrical change. This is basically what happens when a light photon is absorbed in one of the sensitive cells of the retina (the light-sensitive part of the eye). The chemical change in a particular point of the retina triggers an electrical signal to the brain to inform it that a light photon has been absorbed at that point.
3. When light is absorbed, its energy generally appears as heat. This property is the basis for the use in medicine of IR light to heat tissues. Also, the heat produced by laser beams is used to "Weldon" detached retina to the back of the eyeball and to coagulate small blood vessels in the retina.
4. Sometimes when a light photon is absorbed, a lower energy light photon is emitted. This property is known as fluorescence; as you may guess, it is the basis of the fluorescent light bulb. Certain materials fluoresce in the presence of UV light, sometimes called "black light" and give off visible light. The amount of fluorescence and the color of the emitted light depend on the wavelength of the UV light and on the chemical composition of the material that is fluorescing. One may fluorescence is used in medicine is in the detection of porphyria, a condition in which the teeth fluoresce red when irradiated with UV light.
5. Light is reflected to some extent from all surfaces. There are two types of reflection (Fig. 1). Diffuse reflection occurs when rough surfaces scatter the light in many direction. Specular reflection is a more useful type of reflection; it is obtained from very smooth shiny surface such as mirrors where the light is reflected at an angle that is equal to the angle at which it strikes the surface. Mirrors are used in many medical

instruments. One simple instrument is a mirror that is held at the back of a patient's throat to look at his vocal folds.

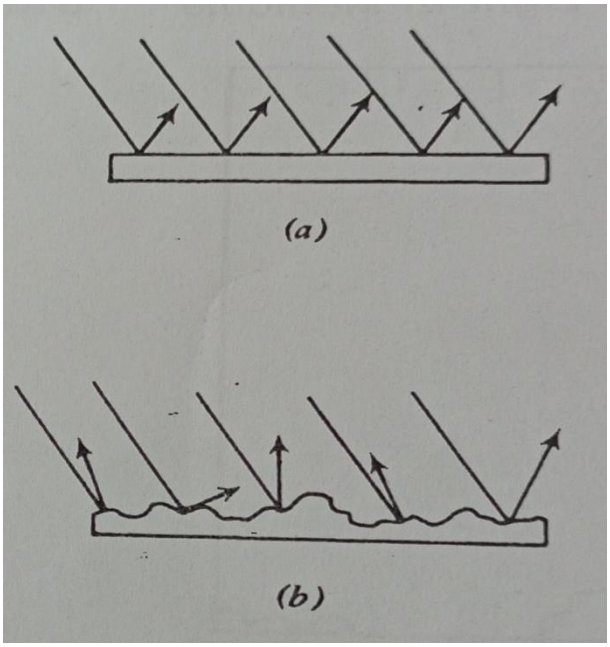

Figure 1

Measurement of light and its units

The three general categories of light-UV, visible, and IR-are defined in terms of their wavelengths. Wavelengths of light used to be measured in microns ($1\mu=10^{-6}$ m) or in angstroms ($1\ ^{\circ}A=10^{-10}$ m), but at present the recommended unit is the nanometer ($1\ nm=10^{-9}$ m). Ultraviolet light has wavelengths from about 100 – 400 nm; visible light extends from about 400-700 nm; and IR light extends from about 700 to over 10^4 nm. Each of these categories is further subdivided according to wavelength (λ). For example, UV-C has wavelengths from about 100 to 290 nm, UV-B has wavelengths from 290 to 320 nm, and UV-A has wavelengths from 320 -400 nm.

Visible light is measured in photometric units. All light radiation, including UV and IR radiation, can be measured in radiometric units.

Light is a form of energy, it is sometimes useful to talk about the energy of individual light photons. Figure 2 gives the energies as well as the wavelengths of the different parts of the electromagnetic spectrum.

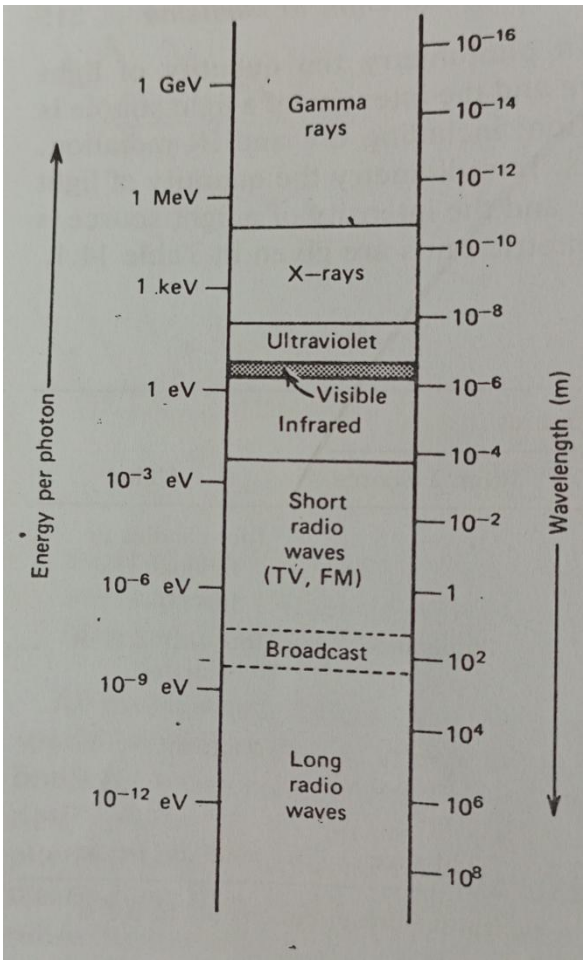

Figure 2

Applications of visible light in medicine

An obvious use of visible light in medicine is to permit the physician to obtain visual information about the patient regarding, for example, the color of his skin and the presence of abnormal structures in or on his body.

A number of instruments, called endoscope, are used for viewing internal body cavities. Special purpose endoscope are often given names indicating their purpose. For example, cystoscopes are used to examine the bladder, proctoscopes are used for examining the rectum, the bronchoscope are used for examining the air passages into the lungs.

Transillumination is the transmission of light through the tissue of the body and its used :

1. In the detection of hydrocephalus (water-head) in infants.
2. To detect pneumothorax (collapsed lung) in infants.

Visible light has an important therapeutic use. Since light is a form of energy and is selectively absorbed in certain molecules, it should not be surprising that it can cause important physiological effects. Many premature infants have jaundice, a condition in which an excess of bilirubin is excreted by the liver into the blood. Relatively recently (1958) it was discovered that most premature infants recover from jaundice if their bodies are exposed to visible light (phototherapy). The exact mechanism is not clear, but blue light (~450 nm) appears to be the most important component.

Applications of ultraviolet and infrared light in medicine

The wavelengths adjacent to the visible spectrum also have important uses in medicine. Ultraviolet photons have energies greater than visible photons, while IR photons have lower energies. Because of their higher energies, UV photons are more useful than IR photons.

Ultraviolet light with wavelengths below about 290 nm is germicidal that is, it can kill germs and it is sometimes used to sterilize medical instruments. Ultraviolet light also produces more reactions in the skin than visible light. Some of these reaction are beneficial, and some are harmful.

Ultraviolet light from the sun affects the melanin in the skin to cause tanning. However, UV light can produce sunburn as well as tan the skin. The wavelengths that produce sunburn are around 300 nm, just at the edge of the solar spectrum (Fig. 3).

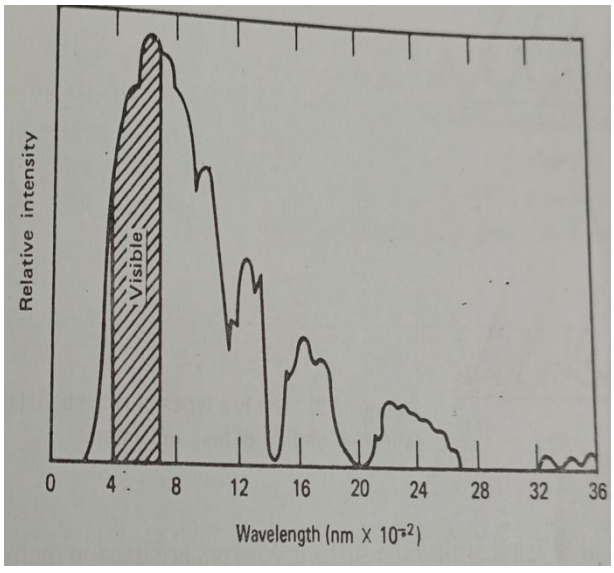

Figure 3

Solar UV light is also the major cause of skin cancer in humans. The UV wavelengths that produce sunburn are also very well absorbed by the DNA in the cells.

The large percentage of near-UV light absorbed by the lens may be the cause of some cataracts (opacities of the lens).

About half of the energy from the sun is in the IR region (Fig. 3). The IR rays are not usually hazardous even though they are focused by the cornea and lens of the eye onto the retina. The IR wavelengths can cause a burn on the retina.

Heat lamps that produce a large percentage of IR light with wavelengths of 1000-2000 nm are often used for physical therapy purposes. Infrared light penetrates further into the tissues than visible light and thus is better able to heat deep tissues.

Two types of IR photography are used in medicine: reflective IR photography and emissive IR photography. The latter, which uses the long IR heat waves emitted by the body that give an indication of the body temperature, is usually called thermography. Here reflective IR photography, which uses wavelengths of 700-900 nm to show the patterns of veins just below the skin. Some of these veins are visible to the eye, but many more can be seen on a near-IR photograph of the skin.