The nature of light
Date: Venerdì, febbraio 15 @ 12:23:24 CET
Topic: Educational Lighting Site

Light is a physical phenomenon of energetic nature. If, for instance, we heat a metal body, up to a certain temperature, we obtain a light emission. The propagation occurs in the form of radiations in the empty space and in solid, liquid and aeriform materials, which we consider transparent to light. A scientific theory - the undulatory theory of light - interprets these radiations as electromagnetic waves: a cyclical alternation of concatenated electric and magnetic fields, generated by very rapid oscillations of electric charges, which vary their intensity with a sinusoidal law and perpendicularly to the direction in which the radiations move. A light beam is made of a set of electromagnetic waves that are transversal to the direction of propagation. Given that it is an undulatory phenomenon, the electromagnetic radiation is characterized by two physical dimension: wavelength and frequency. Wavelength, usually indicated with the Greek letter ?, is the distance, expressed in nanometers, travelled by the wave during a complete oscillation cycle. The nanometer - a unit of measurement adopted by the CIE - is a submultiple of the metre: one nanometer (nm) equals one billionth of a metre: 1 nm = 10 m-9 . Frequency, which is symbolized by the Greek letter v, is the number of complete oscillation cycles which occur every second. It is expressed in hertz (Hz): 1 hertz equals 1 cycle per second. Both condensed, i.e. solids and liquids, and aeriform materials, i.e. gases and vapours, that are maintained at a temperature exceeding absolute zero, generate electromagnetic radiations with different wavelengths and frequencies. All known radiations are represented by the electromagnetic spectrum. The wavelength interval contained in the spectrum is wide: from 10-5 nm to 1016 nm. Microwaves have many applications, these radiations, measured in millimetres, have frequencies that extend from about 1 gigahertz (1G Hz = 109 Hz). They have been adopted by satellite communications, research into the physics of particles and radio astronomy, remote sensing, in medicine for diagnosis purposes and antitumour therapies. The use in the home is related to intrusion alarm systems and microwave ovens. This latter use exploits the particular property of microwaves of dispersing part of their energy in the form of heat inside the intercepted bodies. The property of transferring thermal energy characterizes the entire family of infrared radiations, which occupies the spectrum from = 1mm to = 780 nm. In tab. 1.1 are shown infrared radiations with the symbols (IR-A, IR-B, IR-C) and the division by wavelength intervals established conventionally by the CIE.

Tab. 1.1 CIE classification of radiations included in the infrared spectral band

Infrared radiations	**Wavelength interval (nm)**
IR-A	**780 1400**
IR-B	**1400 3000**
IR-C	**3000 1000000**

A practical conventional grouping criterium is used for ultraviolet radiations too which is based on the acronyms UV-A, UV-B, UV-C, which serves, as we shall see better further on, to classify them in terms of the effects produced on the irradiated living organisms and materials. The ultraviolet rays band is partly superimposed on the X rays band which, in their turn, invade the range of gamma rays. X rays are the known radiations with a very short wavelength and a very high frequency produced by man-made instruments. Gamma rays issue from nuclear explosions. From the sidereal space we receive both gamma rays and cosmic rays. Together they occupy the extreme area of the spectrum. The radiations which the human visual organ is able to receive and translate in nervous impulses occupy a small portion of the spectrum: from 380 nm (at the limit of ultraviolet) to 780 nm (at the limit of infrareds). We define light the sensation produced by radiations comprised between these extreme values. Only inside this interval the human visual apparatus performs its functions: to receive, select and structure the radiations coming from the outside and transform them in nervous signals to send to the lobes of the cerebral cortex, where they are codified through the complex chain of physical-chemical reactions which are at the basis of the phenomenon of visual perception.

SEZ.1-BIS

In that small region of the electromagnetic spectrum is concentrated the indispensable energy of the entire biosphere. The whole vegetable world lives and reproduces itself by transforming the energy contained in light radiations in chemical energy, through the well known process of chlorophyll photosynthesis. Thanks to light, complex organic substances, built from carbohydrate molecules are synthesized with the release of oxygen in the air, starting from simple inorganic substances. The reproduction of plants - the first link of the food chain - provides the basic materials for the life of animals and human beings.

To better understand the concept of wavelength associated to a light radiation let us take into consideration a few examples (fig.1): the aspects to consider would be many. Moreover, the problems linked to the manufacturing of lamps and the functions required from illumination in varied applications are manifold, but by greatly simplifying it is possible to make the following considerations.

- The sun light has a continuous spectrum (i.e. it contains radiations of all wavelengths); incandescent or halogen lamps, whose operating principle is based on the emission of light by an incandescent filament (thermal radiators, like the sun) have a continuous spectrum too, with a higher intensity in the band of infrared rays; in discharge lamps (whose operating principle is based on the principle of the discharge of gases: the light is generated by an arc between two electrodes inside a discharge tube containing gas) the gases, when the discharge current is activated and according to the pressure conditions present in the lamp, are excited and made emit energy in the shape of radiations with different wavelengths.

- For instance, sodium at low pressure emits in the yellow band, at high pressure mercury at 365 nm, 405, 436, 546 and 578 which are in the band of violet, blue and green, etc. It follows that the spectrum can comprise individual distinct lines (for instance halide lamps); the higher the number of substances contained in the discharge tube the nearer the spectrum will be to a continuous spectrum (in HMI lamps for photo-optics the almost continuous spectrum is obtained through the insertion in the discharge tube of a high number of substances amongst them the so called rare earths, metals like dysprosium, tullium, holmium.

At this point, without entering into details, it is important to very briefly outline the operating mechanism of the human eye. The human eye is, in short, an optic system in which the crystalline acts as a lens and the retina as a light detector through a series of receptors (cones and rods) connected to the brain through the optic nerve.. The human eye adapts its sensibility partly thanks to the opening and the closing of the iris, partly with a process of adaptation which includes the passage from "photopic" vision, that is day vision, (which involves the cones) to "scotopic" vision, that is night vision, (which involves the rods); the focussing takes place through the variation of the curvature of the crystalline. The eye adapts to great variations of the environment (between light and night illumination the levels of light can differ between them up to 10,000,000 times).

- each wavelength of the visible radiation is perceived by the human eye in the shape of a specific colour of the spectrum (e.g. 555 nm yellow-green, 400 nm violet, 700 nm red).

The eye, however, is not equally sensible to all wavelengths from 380 to 780 nm and its sensibility varies according to day and night illumination. On the basis of many experiences on numerous observers, the CIE (Commission International De l'Eclairage-International Organization which publishes reports and recommendations on measurement procedures and the performances of systems in the illumination sector) has defined the spectral sensibility curves of the human eye, normally indicated with the acronym V(I), in which it reports the state of the sensibility of the human eye (in relative values) on the basis of the wavelength under both day and nighttimes conditions.

Illumination has the purpose of bringing the human eye to function with a photopic vision even at night: the curve which interests us, thus, is the one in photopic vision. In fig.2 is shown the V(I) curve which is fundamental in all measurements of light.

As it can be seen, the maximum sensibility of the human eye occurs with 555 nm (yellow-green); an equally intense radiation but with a different wavelength causes a visual sensation of lower intensity: e.g., for radiations with a 490 nm wavelength, the sensibility of the eye equals 20 percent compared with that for radiations with a 555 nm wavelength.

Fig.1-Examples of spectral distribution of different types of lamps a) halide vapour discharge lamp for photo-optics; b) sodium vapour at low pressure lamp; c) incandescent lamp; d) halide lamp.

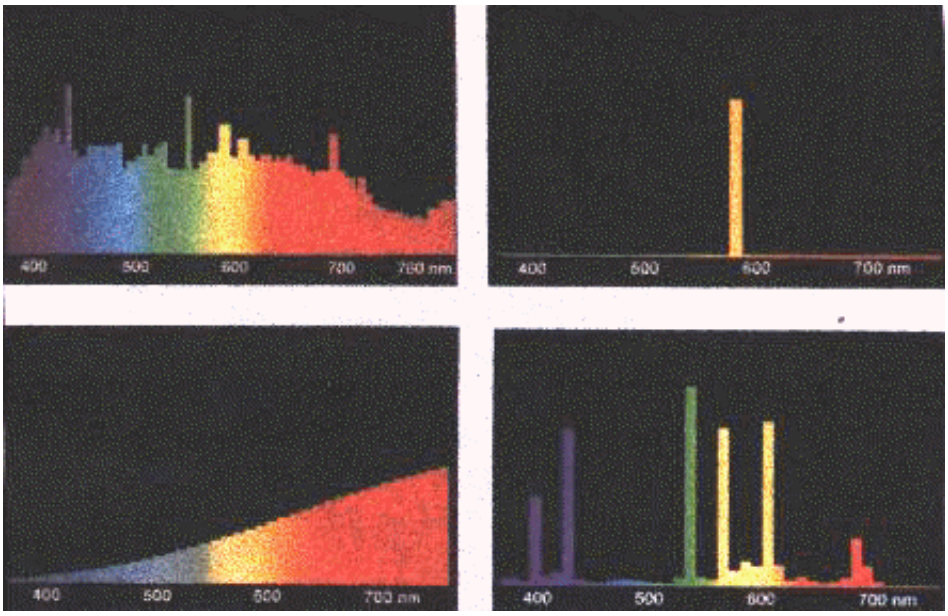
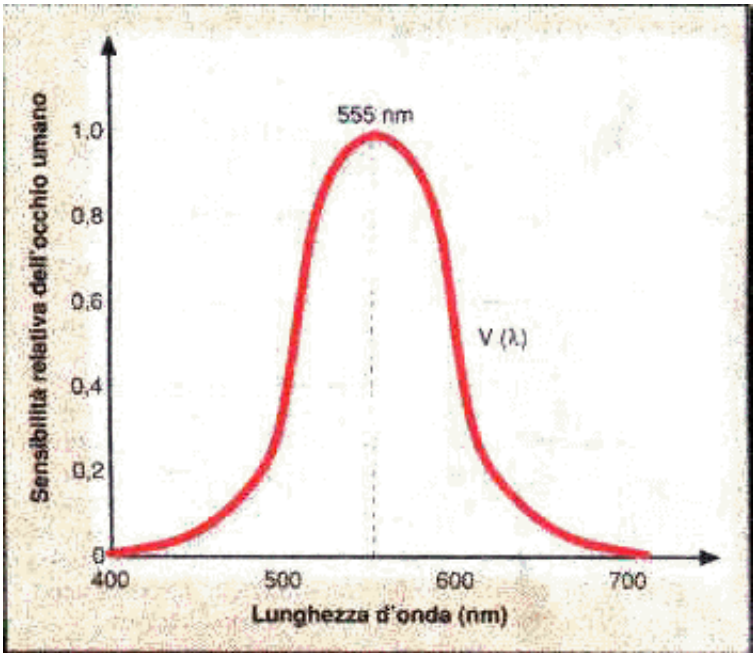


Fig.2-Sensibility curve of the human eye V



Sensibilità relativa dell'occhio umano
1,0
0,8
0,6
0,4
0,2
0
555 nm
V (λ)
400
500
600
700
Lunghezza d'onda (nm)