Photometry

Photometry is the field of optics describing light and its effects on the human eye . Using photometric quantities, it determines the properties of light sources and illuminated surfaces. Another possible definition of photometry is "the measurement of light that is detected by the human eye".

Photometry

We include the following topics in the Photometry exam question, elaborated in detail in the following articles:

- Radiometric and photometric quantities and units and their interrelation
- Spectrophotometry :
  - Light absorption
  - Beer's Law - in czech
  - Lambert-Beer's law
- Sources and detectors of optical radiation :
  - Types of light sources - light bulbs, luminescent radiation sources, discharge lamps, light emitting diodes, lasers - mutual comparison and character of their spectra - in czech
  - Optical radiation detectors - in czech

Quantities

A brief summary follows (see Radiometric and photometric quantities for more details):

Radiometric quantities

Radiometric quantities consider radiation in the entire energy spectrum, regardless of how the radiation is perceived by the human eye.

Radiant energy (energy sent, transmitted or received in the form of radiation) spreads from the source - as if it "flows", and therefore the total amount of energy that "flows" from the source per unit of time in all directions is called the **radiant flux** , and its unit is the **watt (W)** . To illustrate, we can imagine that a light bulb with an input of 1 W emits a current of 1 W - but the greater part falls on invisible infrared radiation and we do not even count heat losses caused by conduction or flow in addition to radiation.

Radiation intensity is a radiant flux passing through a unit area oriented perpendicular to the direction of radiation propagation, and thus its unit is **W/m^2 .**

Photometric quantities

Unlike radiometric quantities, photometric quantities only consider the part of the electromagnetic spectrum that is perceived by the human eye as visible light.

The basic photometric unit (the SI base unit) is 1 candela as a unit of luminosity; expresses the luminosity of a point source that shines in all directions. In the course of history, its definition has changed, but the name is based on the luminosity of one candle, which previously served as the norm of luminosity, and this idea is still sufficient for a rough idea.

The luminous flux is then the part of the light that such an omnidirectional source with a luminosity of 1 cd emits into a spatial angle of 1 sr and its unit is the *lumen* .

If the luminous flux of 1 lm is spread evenly over an area of 1 m^2 , then the illumination of this area is 1 lx.

Efficiency of the light source

In practice, we are interested in what part of the total energy supplied to the light source will be converted into useful, i.e. visible light; this efficiency is expressed *by the ratio of light and luminous flux.* and its unit is therefore *lumens per watt* [lm/W]. An ideal monochromatic source that would convert all energy into the light to which the human eye is most sensitive (540×10^{12} Hz) would have a theoretical efficiency of 683 lm/W.

Radiation sources

Fire

For many millennia, the light emitted by burning was the only available artificial lighting. At first, the light emitted by the fire had to be sufficient for illumination, later it was lit by rays. Oil lamps and wax or later paraffin candles were invented. The luminous efficiency of the candle is only a few tenths of W/lm, the vast majority of radiation lies in the infrared (thermal) region.

Light bulbs

60W light bulb

Light bulbs are the most common sources of light radiation . They are based on the principle of converting *electrical* energy into *light* energy by heating a thin, most often tungsten wire. At high temperature, it turns into a source of electromagnetic radiation mainly in the infrared light range, a smaller part is also in the visible light range.

Thomas Alva Edison is considered to be the inventor of the light bulb , who built the first light bulb in the 19th century, although experiments with heating the wire were carried out 20 years earlier.

Advantages	Disadvantages
Continuously adjustable	Low efficiency
Simple production	Short lifespan
Easily dismantled	High operating costs
No dangerous radiation	Some emit UV radiation
Sun-like light	

The efficiency of the light bulb is very low, on the order of 10 lm/W, i.e. that the bulb heats more than it lights.

Halogen bulb

A special type of light bulb with a higher temperature reached at the filament and therefore emits radiation with a shorter wavelength than a normal light bulb, therefore it has a **higher efficiency**, which is caused by a greater proportion of visible light. A longer service life is also achieved with them by adding halogen . Its efficiency is approximately 20 lm/W.

Discharge lamps

A discharge lamp usually consists of a glass tube containing some diluted gas (or vapors of some element), which is ionized and a steady electric discharge takes place in it. The type of gas or gas mixture determines the color of the discharge (eg: neon – red-orange, sodium – yellow). The discharge can also emit radiation in the ultraviolet region.

Fluorescent lamp

A fluorescent lamp is a type of discharge lamp that uses argon and mercury vapor. The discharge emits UV radiation , which falls on the luminophore applied to the walls of the fluorescent lamp, which then emits visible light, the spectrum of which is determined by the composition of the luminophore. The efficiency of fluorescent lamps is roughly between 50-100 lm/W.

Luminescent sources of radiation

Luminescence is a phenomenon in which an atom is excited and *then* returned to its original state, when electrons returning to their original state release excess energy in the form of an emitted photon . In addition to fluorescent lights, there are other types of luminescence, such as bioluminescence, known from rotting tree stumps; or midges.

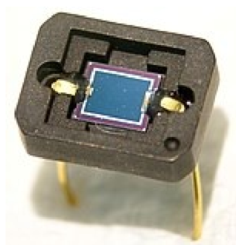
LED

Light emitting diodes are modern light sources with high efficiency, exceeding 100 lm/W.

Lasers

See Laser article .

Optical radiation detectors



Photodiode

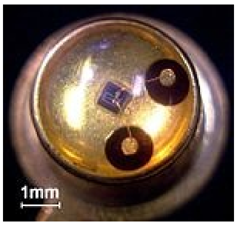
Radiation detectors process the incident energy emitted by the source. After the absorption of energy, the physical properties of the detector change, e.g. the release of electrons in photoelectric detectors or a temperature change in thermal detectors of optical radiation. The oldest and relatively sensitive detector of optical radiation is the human eye.

Optical radiation detectors are **divided into three groups according to the principle** on which they work:

1. **Thermal detectors** use the conversion of the energy of optical radiation into thermal energy. They therefore detect an increase in the temperature of some of their parts (sensors). This change was caused by incident optical radiation. Thermal detectors tend to be non-selective (see below), but only in the optical radiation wavelength range of 0.2-50 micrometers. The most commonly used heat detectors are thermistors , thermocouples and

pyrometers . They are most often used to detect infrared radiation .

2. **Photoelectric detectors** use the conversion of the energy of optical radiation into electrical energy. They are based on *photoconductivity changes, photodielectric effect (permittivity change caused by excitation of detector atoms)* , or internal/external photoelectric effect . Photoelectric detectors belong to the group of selective detectors (see below). The most commonly used photodiode . Other photoelectric detectors are phototransistors , photoresistors , photoelectric cells and photoelectric cameras .
3. **Photochemical detectors** use photographic materials to detect radiation. The energy of optical radiation is used here to initiate a chemical reaction. A measure of absorbed energy is the density of the developed photographic image. A photographic emulsion is most often used as a photochemical detector.



Phototransistor

We **divide** the detectors **according to the type of detection :**

- **direct detection** is the detection of optical radiation in which the radiation detector has the same resonant frequency as the measured optical radiation
- **Indirect detection** is the exact opposite of direct detection

For all types of optical radiation detectors, we also describe their **four basic parameters :**

- **Detectivity** - shows the detector's ability to detect information transmitted by radiation. It results from the threshold value of the detectable power of optical radiation.
- **Conversion efficiency** - is most often defined as the ratio between the resulting energy and the energy entering the detection process.
- **Time response** - the period of time during which the output signal of the detector changes significantly.
- **Spectral characteristic** − is the dependence of the output value of the detector on the frequency of the incident radiation. If the spectral characteristic is constant over a large range, we call the detector non-selective. In the opposite case, i.e. if it is not constant, we are talking about a selective detector.
  - **A non- selective detector** is in no way affected by the wavelength of the incident radiation. These are, for example, heat detectors.
  - **Selective detectors** are influenced by the wavelength of the incident radiation. These are, for example, photoelectric detectors.

All types of detectors that are used today are classified as indirect detectors (see below). If we wanted to use direct detectors, their dimensions would have to be in the range of several micrometers and the entire complex would have to have a frequency of 10 15 Hz . This is currently not achievable with available technologies.

Human eye

The human eye is the oldest and quite sensitive detector of optical radiation. It is spectrally selective in the wavelength range of 400 to 800 nm (some authors also mention 400 to 700 nm). The human eye is most sensitive to a wavelength of 555 nm. It is able to detect the light flux as low as several tens of photons per second. The human eye contains two other types of optical radiation detectors, cones and rods. The sensitivity of these two detectors is not constant, as a result we can observe adaptations of the eye (automatic adaptation of the eye to the input intensity of optical radiation).

Light absorption

Absorption of light is a physical phenomenon in which the intensity of radiation weakens, and the monitoring of which belongs, among other things, to the field of spectrophotometry, which uses it to determine the properties of samples. In general, it can be said that light absorption is the absorption and attenuation of radiation during its propagation through space.

The principle of absorption

A condition for light absorption is a higher number of valence electrons at a lower energy level. (The opposite process to absorption is called **spontaneous emission** , and it, on the other hand, requires more electrons at a higher level for its progress). We look at light as a stream of photons with a certain energy, which is absorbed by another object during absorption, for example an atom, whose valence electrons are currently in the transition between two energy levels and can therefore go to a higher state thanks to this energy gain. During this process, the photon disappears, the energy is absorbed by the object and can subsequently be converted into thermal energy (i.e. the kinetic energy of the particles) or be emitted again (the conversion back into light energy is called luminescence). In principle, we can therefore say that light is transformed into another type of energy during absorption.

Light absorption is described by Lambert's law, which works with quantities such as light intensity, transmittance, thickness of the medium and the absorption coefficient, which indicates the degree of absorption.

Types of absorption

- **Neutral absorption** , which occurs equally at all wavelengths in a certain range of the spectrum.
- **Selective absorption** , in which the light of the entire spectrum is not absorbed, but only a certain part of it. This type of absorption is most typical for most substances that appear colored to us thanks to this phenomenon. This is due to the fact that the light loses some wavelengths or even entire parts of its original

spectrum through absorption. The color of an object is therefore determined by the composition of colors corresponding to the wavelengths of light that the given object absorbs. See subtractive color mixing .

- **Continuous absorption** , in which radiation is absorbed at all wavelengths.
- **Line absorption** , in which radiation is absorbed only in certain spectral lines, which are the components of the line spectrum.

Beer's Law

Beer's law describes the dependence of the absorption coefficient on the concentration of the substance (or the concentration of absorbing molecules in a non-absorbing solvent):

$$\alpha = \varepsilon \bullet C,$$

where ***α* is the absorption coefficient** , ***C* is the concentration of absorbing molecules** and ***ε* is the molar absorption coefficient** – a constant that characterizes the absorbing substance and depends on the wavelength of the passing monochromatic radiation (it is a function of it).

Lambert-Beer law

The Lambert-Beer law determines absorbance , a quantity characterizing the rate of absorption of electromagnetic radiation in a substance.

Absorbance depends on the thickness of thewhere the radiation is attenuated, and on the absorption coefficient(attenuation), which depends on the intensity .

$$A = \alpha \cdot d$$

We substitute Beer's law into this formula , where is the molar absorption coefficient and is the molar concentration of the solution:

$$\alpha = \varepsilon \cdot C$$

We thus obtain the Lambert-Beer law:

$$A = \epsilon \cdot C \cdot d$$

Links

- Laser

External links

- Light transduction (https://www.youtube.com/watch?v=KosDT4z6NBc%7C)
- Spectral sensibility of the human eye (anglicky) (https://www.telescope-optics.net/eye_spectral_response.htm)

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