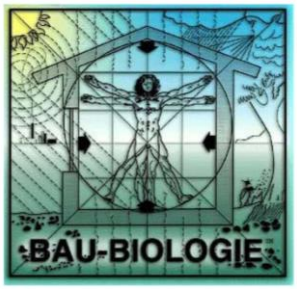
International Institute for Bau-biologie® & Ecology

IBE 204.5

# IBE 204.5 Light & Lighting

**BRINGING TOGETHER TECHNOLOGY AND DESIGN METHODS TO PROVIDE THE INFORMATION NEEDED TO CREATE HEALTHY HOMES AND WORKPLACES**




# Light & Lighting – IBE 204.5

## Welcome

*Thank you for choosing IBE for your educational needs. Current environmental realities demand a new approach to ensuring that our homes, schools and office buildings support the health and wellness of all who dwell there. We strive to provide the latest information and cutting edge methodology on the vital, complex relationship between the natural and the built environments. May you find your educational experiences enlightening, and take this knowledge out into your community for the benefit of all.* **Michael Conn**, *Executive Director*, Institute for Bau-Biologie & Ecology.

## Course Navigation

You will find that it is very easy to navigate through this course.

- Progress through the lessons using intuitive navigation tools. When you study, make sure to be aware of and use all supporting materials, such as pdf files, video and audio clips, links to other websites or relevant articles or papers, as well as the online forum.
- The last lesson will give you the option of downloading an electronic version (PDF) of the course. Please be aware that this information is copyright protected.
- When finished, you will be ready for the test. These tests are "open book" and are designed to help you evaluate your understanding of the subject.
- When you have finished the entire Course Pack, a Certificate of Completion is available on-line.

By using the Forum feature, students can share information and solve problems. We would like to see truly interactive discussions take place.

Please be advised that links to third party information may not reflect or support the Building Biology viewpoint. However, it might be of some interest to see how other people, groups, institutions, etc. argue the same subject.

## Copyright



Direct all inquiries to:

General Information: **infopod@buildingbiology.net**
Technical Support: **techsupport@buildingbiology.net**

Phone:**1-866-960-0333** (toll-free in US & Canada)

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# Lesson 1 - Natural Light

The sun is more than the visible center of our planetary system; it is also the source of all living things. Without light there would be no air, no water, no earth, and no fire. First there was light, and then there were humans.

With the notable exception of some bacteria hidden inside igneous rock thousands of feet below earth's surface, all life forms need light. Plants, animals, and humans depend on it for their growth, biorhythms, health, and well-being.

With the help of sunlight, those plants equipped with green "solar panels" in the form of chlorophyll magically transform inorganic substances into organic ones, thereby providing animals, humans, and themselves with food. This magnificent process is called photosynthesis.

Light is also the medium for one of our most important sensory systems: *vision*. The sun's energy impacts humans both physically and emotionally.

*"There where the sun does not shine the physician will have to go."* Proverb

Watching a sunset or sunrise provides us with a glimpse into the significance of light.

Natural Light Basics

Light is energy in the form of radiation. From a physics perspective, optical radiation or light is a rather narrow slice of the broad electromagnetic spectrum. Light usually travels at a speed of 300,000 km per second (186,000 mps) across empty space, which is why this speed is also referred to as light speed.

Though the sun emits energy across the entire electromagnetic spectrum, protective shields around the earth permit only those wavelengths that are supportive of life to pass through. Our earth home has two major "windows" into space. The "radio window" opens from about 1 mm to 30 m. And the "optical window" opens from about 300 to 900 nm, ranging through the whole visible spectrum from near ultraviolet to near-infrared. In addition there are also several narrow-band, longwave, infrared channels in the micron region (ca. 3 – 14 µ).

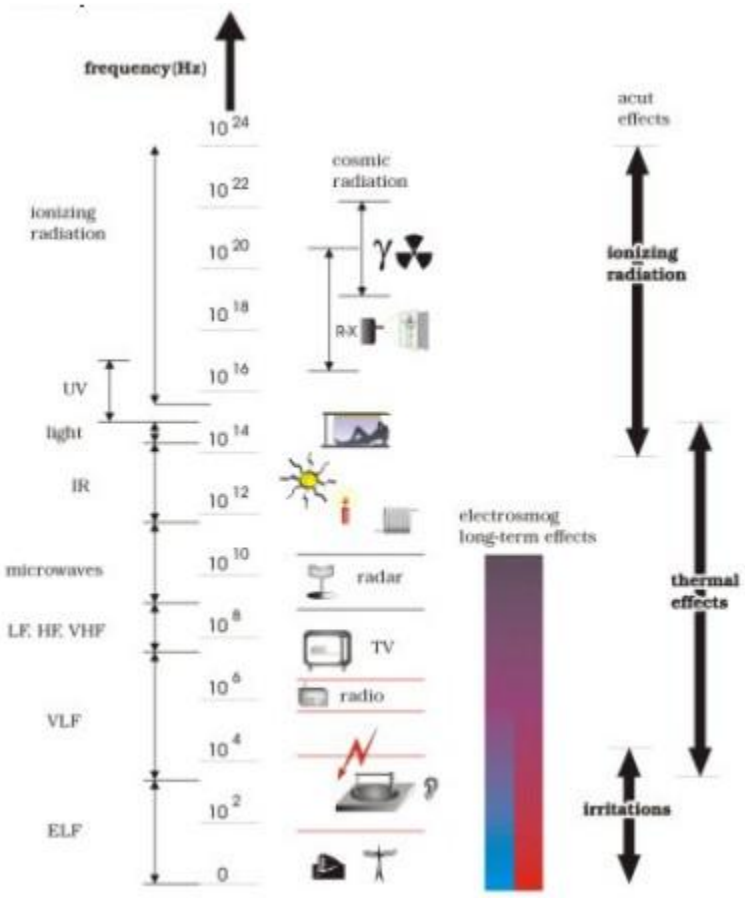


Figure 2: Optical Radiation Is a Small Portion of the Electromagnetic Spectrum

Visible Light

Human perception of visible light begins at about 380 nm and extends to 770 nm. This visible portion of the electromagnetic spectrum is sandwiched between ultraviolet radiation (280 – 380 nm) and infrared radiation (770 – 100,000 nm). For the discussion on the various colors contained within the visible spectrum, see course module IBE 204.4 "Natural Colors."

Ultraviolet Radiation

Ultraviolet radiation is commonly divided into three different sections: UV-A, UV-B, and UV-C.

| | Wavelength | Percent of Total Solar Energy |
|---|---|---|
| UV-A | 315 – 380 nm | 6.3% |
| UV-B | 280 – 315 nm | 1.5% |
| UV-C | 100 – 280 nm | 0.5% |

Most of the sun's UV-A radiation reaches the ground level. UV-B radiation ranges from about 300 nm at ground level to 290 nm higher up in the mountains. Any radiation below 280 nm is almost completely absorbed either by

the ozone layer or by oxygen and nitrogen molecules. Because naturally occurring UV-C radiation is rarely found on the earth's surface, it is not included in the optical radiation.

UV radiation is strongest at the equator where UV rays travel the least distance through the atmosphere to reach the earth. Farther north we go, there is less UV exposure. At about 50$^{o}$ northern latitude – such as in Seattle, Washington (USA) or Frankfurt (Germany) – ultraviolet light is only present for about 4 hours during winter (10 am – 2 pm), but nearly 8 hours during summer (8 am – 4 pm). Note that during winter the UV radiation at this latitude does not contain much if any UV-B, which is required for vitamin-D synthesis in human skin.

UV radiation adheres to the same laws of physics as visible light, including refraction, diffraction, reflection, and interference.

Infrared Radiation

The warming infrared rays cover a broad segment of the electromagnetic spectrum, ranging from 0.77 micron (770 nm) to 1,000 micron (1 mm). Infrared radiation can be loosely divided into three sections:

| | |
|---|---|
| Near Infrared (NIR) | 0.77 to 1.5 micron |
| Middle Infrared (MIR) | 1.5 to 3 micron |
| Far Infrared (FIR) | 3 to 1,000 micron |

Near infrared radiation is located just beyond the red portion of the visible spectrum. Though the sun emits energy throughout the entire infrared spectrum, the earth's atmosphere allows mostly the shorter wavelengths of infrared to penetrate, which are also referred to as reflective infrared.

At about 50$^{o}$ northern latitude, the various components of the optical radiation are found on earth in the following ratio:

Infrared : Visible Light : UV Radiation = 53 : 44 : 3

An intimate knowledge of the spectral composition of natural daylight is essential to building biology lighting design and provides a foundation for evaluating biological effects of various types of light sources.

# Lesson 2 – Health & Light

Health Impact of Infrared Heat - Physiological Effects

Light in its many forms supplies living organisms with critically needed radiation energy, which is absorbed by pigments in the skin, by thermoreceptors in the skin, or by photoreceptors in the retina of the. Light and heat are often interconnected. The physiological effects of light and heat radiation on the human body depend on the intensity, spectral composition, and time cycles.

The thermal effects of infrared radiation are determined by the degree of absorption. For humans the infrared region between 0.7 and 1.4 micron is very important. This near-infrared radiation can penetrate deeply into inner tissues (up to several millimeters), thereby greatly enhancing blood circulation, stimulating the immune system, and speeding up metabolism. In contrast, far-infrared radiation is mostly absorbed at the uppermost skin level.

Building Science Aspects

It should be noted here that solar radiation also contributes to the heat gain of buildings. In cold and mixed climates, this fact can be used to save energy. In combination with air movement and ventilation, heat radiation can also be instrumental in the drying process of walls and buildings.

Infrared radiation as well as UV radiation, however, may cause damage in heat-sensitive materials (e.g. accelerated aging, color fading). Special care needs to be taken regarding high-quality furnishings or pieces of art, particularly in museums, galleries, or churches.

It is the task of the architect to integrate all aspects of indoor climate and energy efficiency with the requirements for maximum daylight exposure. To achieve this goal, while meeting health, ecological and economic requirements, it is highly important to orient a building for its solar exposure and to adjust window sizes in relation to the facing direction.

Health Impact of Visible Light including UV Radiation

Biological effects of light are mediated by three major criteria:

♦ Rhythm ♦ Intensity ♦ Quality ♦

In nature these three criteria are interrelated and determined by the path of the sun. The rhythm between day and night, brightness and darkness is modulated by the "rising" of the sun in the morning and its "setting" towards evening. The intensity of the various colors contained within the visible spectrum of light as well as the portions of UV radiation are constantly changing over a whole day. Due to the ever-changing position of the sun, the atmosphere filters out more or less optical radiation. Humans, animals, and plants respond to these patterns in a holistic way. From medical research, however, we know that each single component can have different physiological as well as psychological effects.

The eye is the major gateway through which light enters the human body. One portion of this incoming light is used for "optical work," affording us the ability to see. The other portion of this light energy is applied toward "energetic work" in other parts of the body. The light information travels along the optical nerve, across the hypothalamus to the pineal gland, which acts as a circadian photoreceptor and timekeeper. The hypothalamus along with the pituitary gland coordinate all the other glands of the body that control metabolic rate, immune system activities, blood pressure, growth, sexual functions, stress responses, and many other functions.

UV-B radiation is also absorbed through the skin, where it transforms cholesterol into vitamin-D. This "sunshine" vitamin is very important for the body's calcium and phosphorous metabolism, fostering healthy bones. A deficiency in UV-B radiation can lead to dental caries and rickets.

Conversely, an overexposure to UV radiation will cause premature aging of the skin as well as skin cancer. The steadily increasing hole in the protective ozone layer and the unreasonable behavior of sun-hungry vacationers are