

Module 1

Illumination Engineering Basics

Lesson 2 Radiation

Instructional objectives

1. State the Visible Range of light.
2. State the range of light human eye responds to.
3. Define UV radiation.
4. Define IR radiation.
5. List the physical phenomenon employed in artificial lighting.
6. Define color temperature.

Introduction

Light is the Radiant Energy that provides visual sensation. It is similar to radiant heat. But has different frequencies and wavelengths. However, Visible Light – spans from 180nm to 700nm wavelength. It must be mentioned that human Eye responds from 380 (violet) to 700nm (red). This becomes necessary for us to understand the suitability of various types of sources of light.

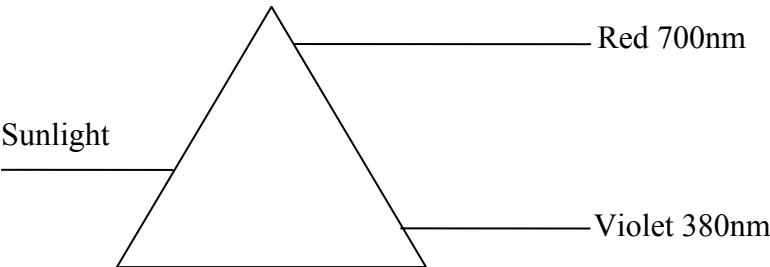


Fig. 1 Spectrum of sunlight when passed through a Prism

Fig.1 shows how sunlight splits into various color bands spread over violet to red often termed vibgyor. Energy is spread over this spectrum from the sunlight. Fig. 2 shows the relative energy content of the solar radiation. While Fig. 3 shows the response of human eye to the solar radiation, which is maxima at about 550nm. (Corresponding to yellow green color).

Relative Energy

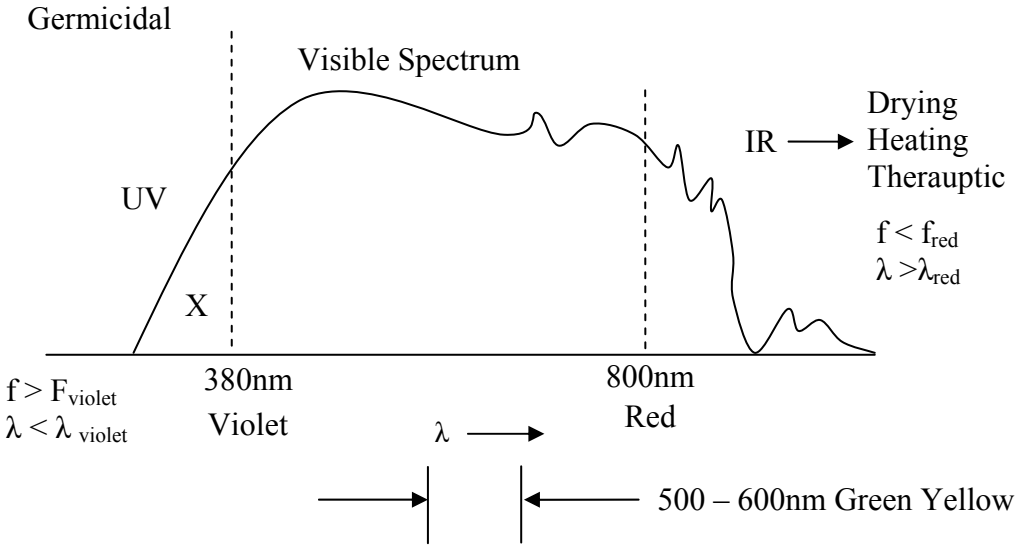


Fig. 2 Spectral energy Content of sun light.

Relative Luminosity

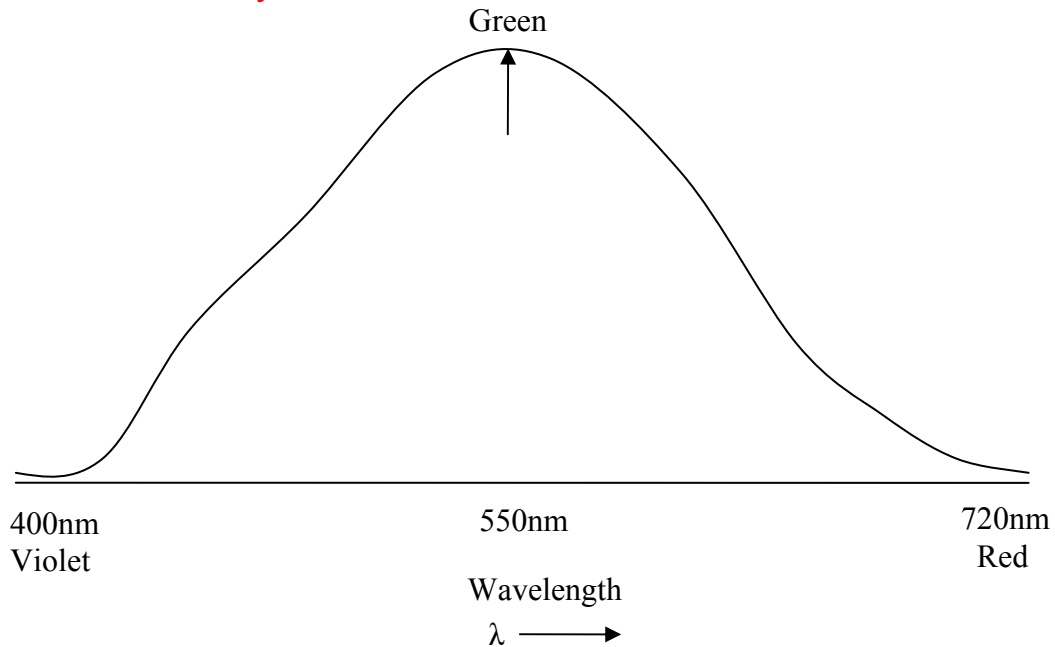


Fig. 3 Luminosity Curve of Average Human

This being the scenario of natural light, artificial sources are made to produce radiation close to this. Artificial sources employed are Incandescent lamps which depend on temperature of the filaments giving a continuous spectrum and gas or discharge lamps giving a discontinuous – Line spectrum / Band spectrum.

Fig. 4 shows the relative energy content of Noon Sunlight, clear blue sky, and an Incandescent lamp. It is seen that the relative energy is peak at about 450nm for blue sky.

Spectral Energy

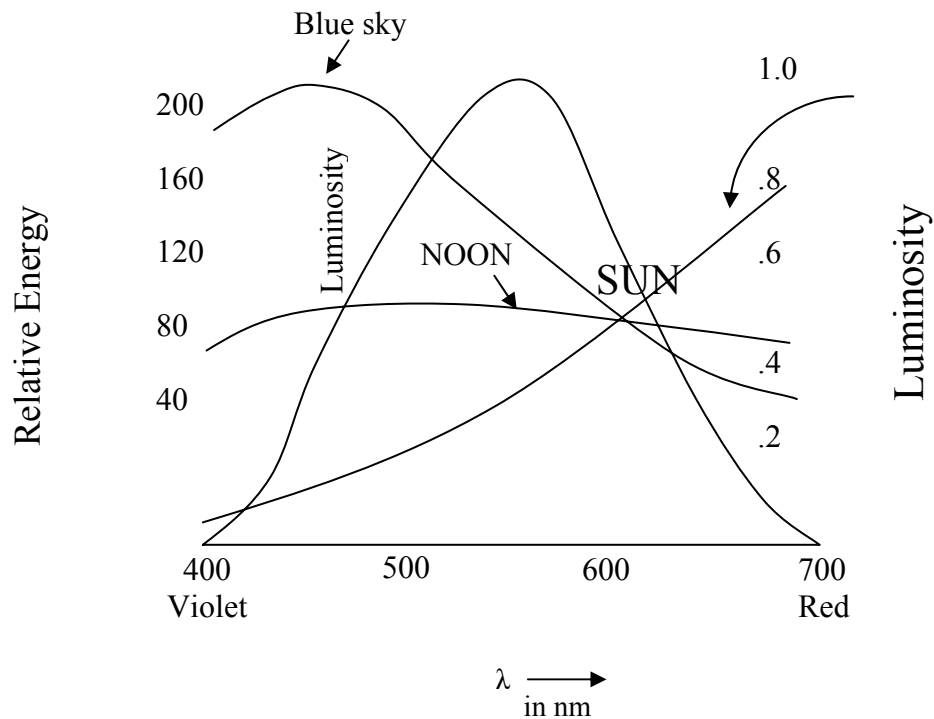


Fig. 4 Spectral Energy Distribution

As may be seen, most of the energy is of low visual value. Even sunlight has very small portion in highly luminous region. Energy content multiplied Luminosity of eye at a particular wavelength gives the Luminosity of the source.

Physical Processes Employed in the artificial sources

1. Incandescence

Thermo luminescence is by definition radiation at high temperature. The sources employing this process are Incandescent Lamp, Gas Lamp, (flames and in oil Lamps and wax candles). They lead to a continuous spectrum of radiation.

2. Luminescence – Luminescence Electro luminescence by definition Chemical or Electrical Action on gases or vapour radiation. Here color of radiation depends on the material employed. Usually this process leads to Line or Band Spectrum.

3. Fluorescence

Fluorescence is a process in which radiation is absorbed at one wavelength and radiated at another wavelength eg: UV impinging on Uranium – Fluorescent oils. This re radiation makes the light radiated visible.

4. Phosphorescence

Phosphorescence is a process when energy is absorbed at some time and radiated later as glow. Examples of this process are Luminous paints that contain calcium sulfide that lead to Phosphorescence. They produce light Radiation after exposure to light.

In practice good efficient lighting is obtained by combining Luminescence and Fluorescence. Fluorescent lamp is Luminescent source of low luminous value activating Fluorescent surfaces which lead to visible radiation. Here intensity depends on gas or vapor involved and phosphor material. However, the temperature of the material play a role in radiation. That is taken up next

Color Temperature

Radiation Temperature of the materials follow Steafan Boltzman's Law:

$$W = kT^4 \dots\dots\dots(1)$$

↓
Absolute °k → Its Boltzman's constant
or
radiation constant
≈ 5.71x10⁻¹²

Say Ambient Temperature is T₀

$$W = k (T^4 - T_0^4) \text{ watts/cm}^2 \dots\dots\dots(2)$$

Thus energy radiated depends on the 4th Power of temperature. So efficiency is high at high temperatures.

Fig. 5 shows the variation of radiation with wavelength for a black body. In each curve total area denotes the energy which increases as 4th power of temperature. Rate of increase of radiation is greater as maxima of radiation shifts with temperature. It goes on till 6500 – 7000° K with 43% radiation visible. This relates to an emission of 90 lm/w

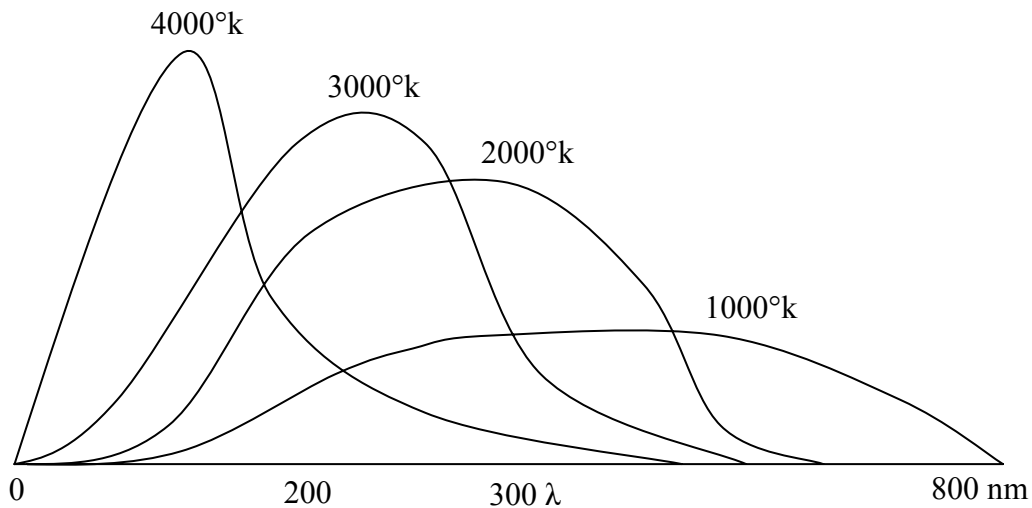
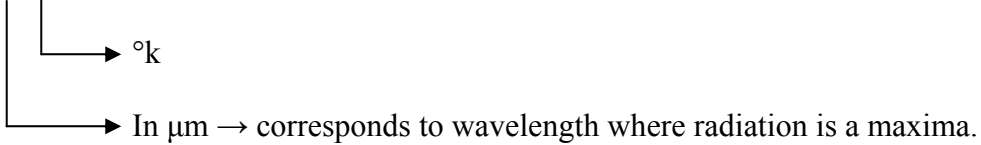


Fig. 5 Black Body Radiation

Wien displacement law

This displacement of maxima is given by wien's law, expressed as

$$\lambda_m \cdot T = a \text{ (constant) } \dots\dots\dots(3)$$

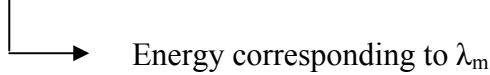


$a = 2960$ for a perfect black body

$= 2630$ for platinum

Combining, (1) and (3) it results

$$W_m T^{-5} = b \text{ (constant) } \dots\dots\dots(4)$$



$$W_m T^{-5} = \text{constant} \dots\dots\dots(5) \quad C \approx 6.0$$

In terms of radiation ability, a body may be called black body or grey body. Black body is one that is not transparent, does not reflect and absorbs all the energy while a Grey Body is one in which energy radiated at each λ is less than that in the case of a black body. That is to say Ratio of $\frac{\text{Visible Energy}}{\text{Total Energy}}$ (remains same). It remains same or reflects a percentage of energy at each

wavelength. Carbon filament lamp is an example of a grey body. There are bodies of selective radiation also. They radiate less total energy compared to a black body at the same temperature but radiate more energy at certain wavelengths. If this wavelength is in the visible region it will be use full for illumination purpose e.g. Arc Lamps.

Thus color temperature is the temperature at which complete radiator (i.e. a black body) must be operated to match the color of luminous source. Complete scale of color temperature for various natural and artificial sources is shown in Fig. 6. As may be seen color temperature, for Blue sky it is 25000°K ., for a Flourescent Lamp it is 4500°K ., for a 500w day light it is 4000°K . and for a Candle flame it is 2000°K .

This Lecture has attempted at understanding the nature of solar radiation – natural light source. It is seen to have maximum energy content around 550 nm close to sensitivity of human eye. It has also a addressed the physical process employed in creating artificial illumination. Concludes color temperature an important index of radiation.

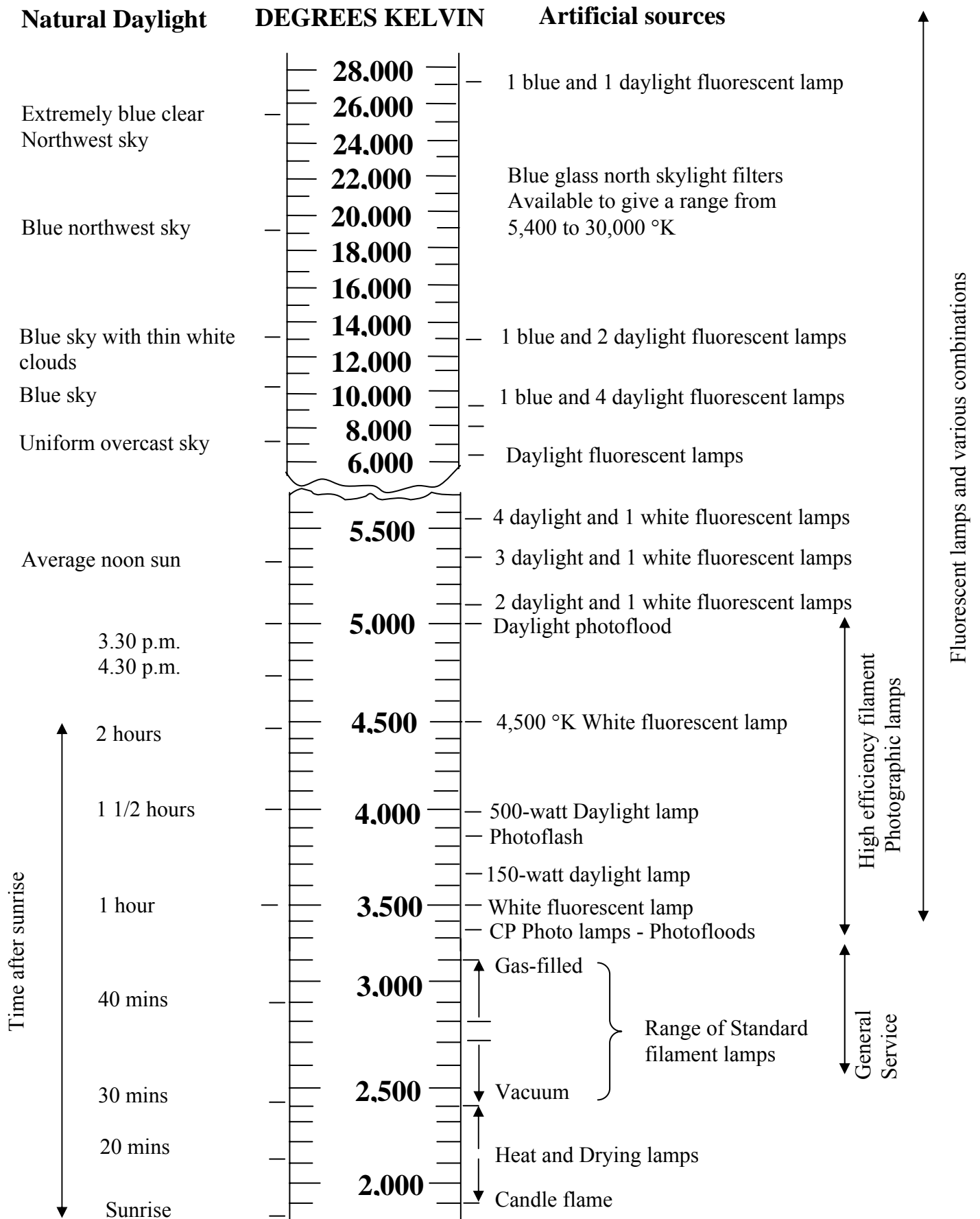


Fig. 6 color Temperature Scale

Lecture Summary

- Light – Radiant energy that provides visual sensation
- Human eye can sense – 380nm (violet) to 700nm (red)
- Maximal relative energy content of sunlight
- Maximal luminosity of human eye
- Artificial light sources
 - Incandescent Lamp
 - Gas Discharge Lamp
- Physical Processes employed for artificial lighting
 - Incandescence
 - Luminescence
 - Fluorescence
 - Phosphorescence
- Good efficient lighting obtained by combining luminescence & fluorescence.
- According to Stefan's-Boltzmann Law & Wien's Law, thermoluminescence, radiation output is directly proportional to the operating temp.
- Color temp. – temp. at which complete radiator (black body) must be operated to match the color of luminous source

Tutorial Questions

- What is the visible range of light? 380nm (violet) to 700nm (red)
- What is the maximal relative energy content of sunlight? 550nm (corresponding to green light)
- Distinguish between incandescent and gas discharge lamps. Incandescent lamps operate on the principle of incandescence, radiation output depends on operating temperature and it gives a continuous spectrum of light while gas discharge lamps operate on the principle of electroluminescence. The output color depends on the material employed and it gives discontinuous spectrum of light.
- Why is it necessary to operate incandescent lamp at maximum possible operating temperature? Due to the fact that the radiation output is directly proportional to the operating temp. of lamp
- State principle of working of a carbon filament lamp. The ratio of the visible energy to the total energy is constant for all wavelengths.
- State principle of working of an arc lamp? They work on the principle that they emit selective radiations in the visible zone.

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