Lighting and Nonionizing Radiation

HSCI 466B
Dr. Peter Bellin
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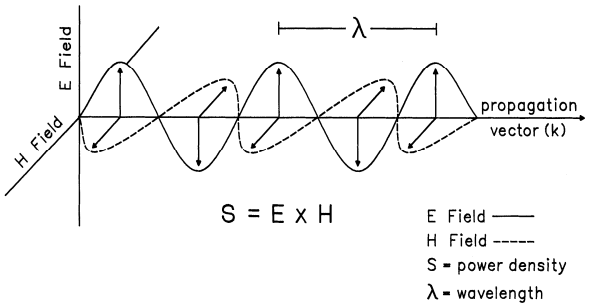
Introduction

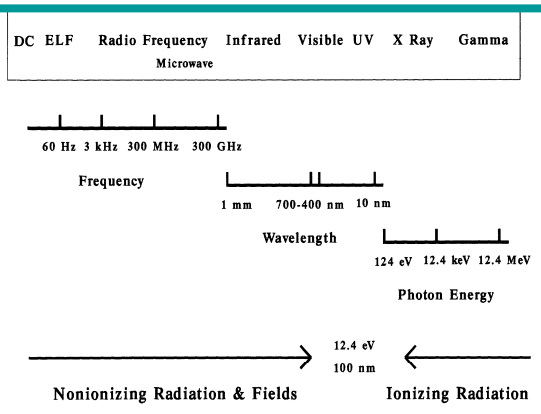
- **Light is combined electrical and magnetic field.**
- **They are co-inducing; Electric field induces magnetic field and vice versa.**

The Waves Represent the Electric and Magnetic Fields



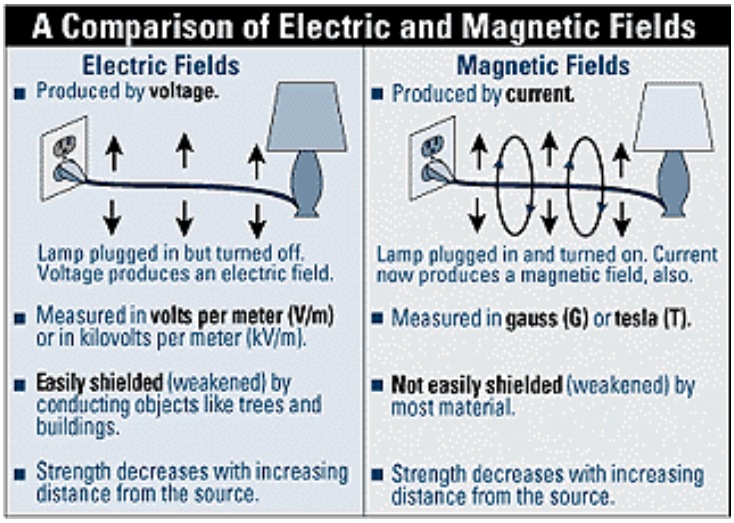
The electric field vector (solid line) is vibrating up and down in the plane of the paper, while the magnetic field vector (dashed line) is vibrating in and out of the plane of the paper. The direction the radiation is moving is defined by a third vector — the propagation vector, k. Electromagnetic fields are transverse to the direction of propagation and contained within the envelope formed by the axis of propagation and the sinusoidal waves.

The Electromagnetic Spectrum



The spectrum is often divided into two regions: ionizing radiation and nonionizing radiation. The boundary between these regions is a photon energy of 12.4 eV.

The Electromagnetic Spectrum



Introduction

- **Electromagnetic radiation: $C = f \lambda$.**
  - **C is the speed of light (3×10^{10} cm/sec)**
  - **F is frequency of vibration (Hz)**
  - **lambda is wavelength**
  - **The higher the frequency, the shorter the wavelength**

Introduction

- **Quantum theory: intensity of light affects number of electrons emitted by a photosensitive cell, but not their energies.**
- **Energy of emitted electrons is related to the frequency of radiation.**
- **Electrons can only absorb radiation in discrete packets (quanta).**
- **$Q = hc/\lambda$**

Introduction

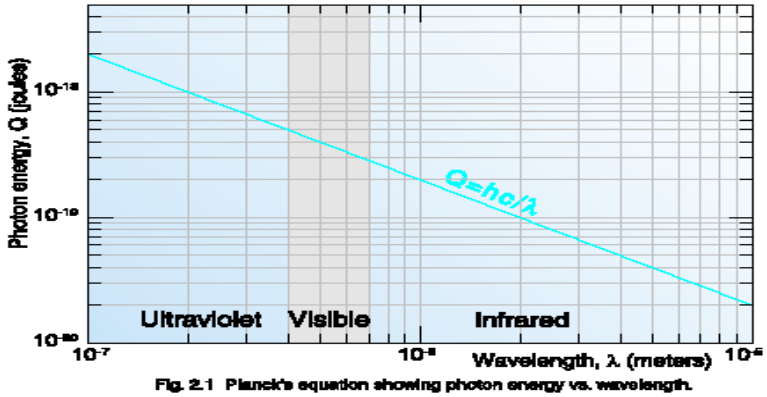


Fig. 2.1 Planck's equation showing photon energy vs. wavelength.

Light Sources

- **Incandescent lights emit white light since transitions (orbitals) may overlap because atoms are closely packed.**
- **A good deal of energy is lost as heat.**
- **Incandescent lamps provide white light, high intensity.**
- **They are hot, having relatively short life span.**

Light Sources

- **Fluorescent lights emit white light through fluorescence**
- **Mercury atoms emit high-energy photons (ultraviolet frequency, 253.6 nm wavelength).**
- **Some of these photons will impinge on the phosphors coating the tube inner surface.**
- **Fluorescent lamps are low-pressure mercury vapor lamps.**
- **Three times as efficient as incandescent lamps.**
  - **Ballast (old models, PCB).**
  - **Mercury.**

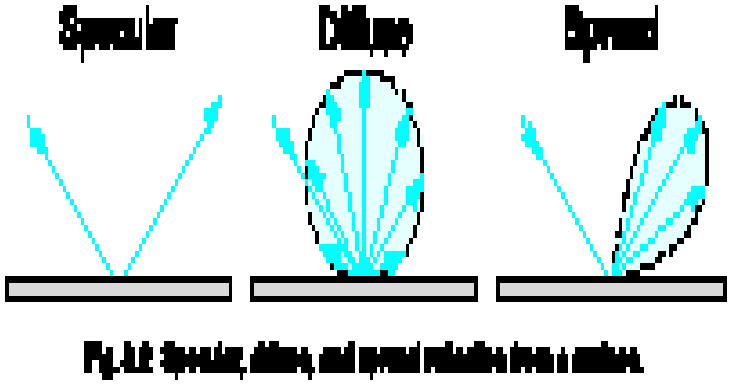
Light Sources

- **Mercury vapor lamps are twice as efficient as incandescent.**
- **Provide yellower light.**
- **Slow to start, slower to restart.**
- **High pressure.**

Behavior of Light

- **Reflectance.**
  - **Light travels in a straight line.**
  - **Part of light incident on a surface is reflected.**
  - **Amount of light reflected is reflectance.**
  - **Specular reflectance is perfect reflection**
  - **Diffuse reflectance, light bounces all over (flour).**
  - **Spread and mixed reflectance are mixtures of specular and diffuse.**

Behavior of Light



Behavior of Light

- **Refraction.**
  - **Light is <u>refracted</u> when it bends in passing from one medium to another.**
  - **Speed of light is slower in different media, due to repeated absorption and emission of photons by materials in a medium.**
  - **Refraction is dependant on the medium and λ.**

Behavior of Light

- **Transmission.**
  - **Transmission of light refers to light's travel through a medium. Partial absorbance occurs, depends on λ and thickness of barrier.**

Behavior of Light

- **Diffusion.**
  - **Light becomes diffuse if light rays are scattered by travel through a medium. Collimation is forming parallel rays of light using a mirror or a lens.**

Behavior of Light

- **Diffraction.**
  - **Diffraction of light occurs when light passes through a narrow slit. The light bends $\Theta = \lambda/D$.**
- **Light is invisible (from the side) unless some matter in its path scatters light to the eye.**

The Human Eye

- **Light passes through the cornea, pupil then lens. It is focused by the lens and regulated by iris. It then passes through the aqueous humor, to impact on the retina.**

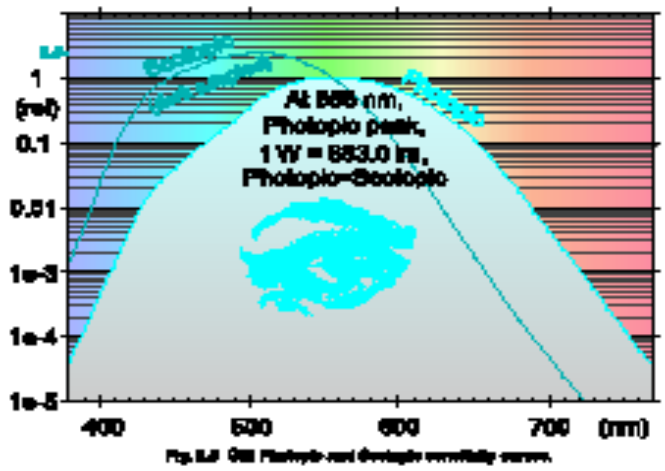
The Human Eye

- **6 million cones and 100 million rods are present in the retina.**
  - **Cones are color sensitive, but insensitive at low light levels.**
  - **Rods are sensitive to low levels of light, not color sensitive. More concentrated on the outer portions of the retina.**

The Human Eye

- **Adaptation occurs in low light levels by manufacturing more rhodopsin. Cones adapt in 10 minutes, and rods adapt in 30 or more minutes.**
  - **Photopic meter copies response of human eye.**
  - **Scotopic meter copies response of dark-adapted eye.**
  - **Either response is wavelength dependent.**
    - **555 nm 10 photons / sec; 450 nm 214 photons per sec; 650 nm 126 photons / sec.**

The Human Eye



The Human Eye

- **Factors involved in seeing.**
  - **Size, or visual angle. How much of the retina does an object cover. Visual acuity refers to the smallest visual angle that can be perceived. Visual acuity increases as light level increases.**

The Human Eye

- **Contrast: color and brightness contrast both affect ability to view and analyze objects.**
- **Brightness: amount of light given off by an object. Depends in part in amount of light striking an object, and how much is reflected.**
- **Time: object must be visible for sufficient time to allow viewing an object.**

Terminology

- **Radiant flux: total radiant power emitted by an object**
- **Luminous flux: radiant power emitted by an object, adjusted to human eye**
  - **Photopic and scotopic**
- **Units are lumen**

Terminology

- **Ω = A cos theta / R^2. There are 4 pi steradians in a sphere.**

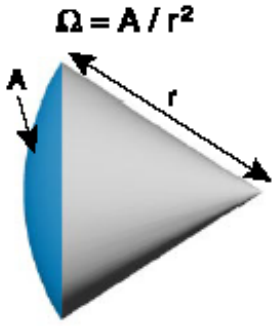


Fig. 7.2 Solid angle

Terminology

- **Lumen: flux falling on a surface 1 m^2 area, one meter from a source with luminous intensity of 1 candela.**

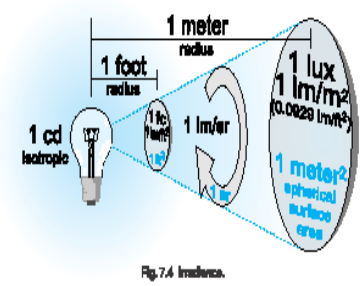


Fig. 7.4 Irradiance.

Terminology

- **Luminous intensity: luminous flux emitted per steradian. Intensity = flux/Ω.**

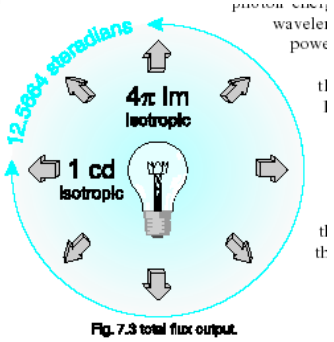


Fig. 7.3 total flux output.

Terminology

- **Irradiance**

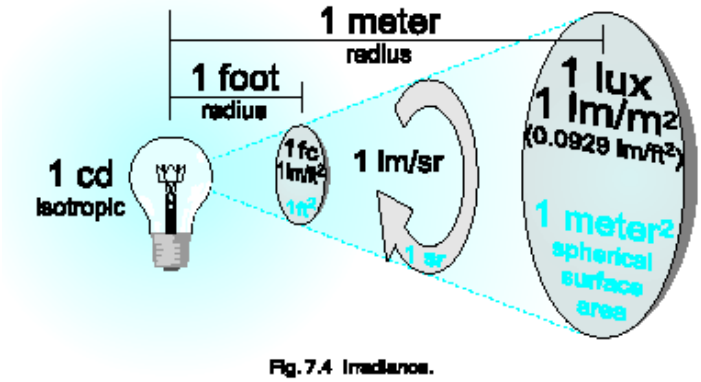


Fig. 7.4 Irradiance.

Terminology

- **Illumination: density of luminous flux on a surface area. Lumens per square foot = foot candle.**

Terminology

- **Luminance: amount of light emitted or reflected by a surface. Measured in foot-lambert units.**

Terminology

- **Reflectance: how much light is reflected by a surface.**
- **Reflectance = luminance / illumination.**

Measurement of Light

- **Foot-candle meter**
  - **Light sensitive material in contact with metal plate.**
  - **Electrons emitted by the light cell are collected by metal plate, setting potential difference between plate and cell.**
  - **This can be measured as a current and displayed in foot candle units.**

Measurement of Light

- **Color correction: filters are used so meter will read light with same sensitivity as the human eye (peak sensitivity in the green region).**
  - **Photopic response.**

Measurement of Light

- **Cosine correction: adjusted for angle of light (into the meter)**

Measurement of Light

- **Adaptation may occur, especially when passing from low light to higher light levels.**

Light Survey Procedures

- **Describe illuminated area: room dimensions, color of walls, surfaces, reflectance, conditions of room surfaces.**

Light Survey Procedures

- **Description of general lighting system: types of lamps, number of lamps, wattages used, how they are arranged, how they are mounted.**

Light Survey Procedures

- **Description of supplementary lighting used.**
- **Descriptions of light measuring instruments to be used.**
- **Illumination measurements: do not cast shadows, do not allow light to reflect from clothing to surfaces, take readings as close as possible to work surfaces being evaluated.**

Light Survey Procedures

- **Conduct luminance measurements.**
- **Compare results with those recommended by consensus or regulatory agencies. Consider ergonomic factors, safety factors, etc.**

Light Survey Procedures

- **Other factors:**
  - **Glare (effect of brightness differences within visual field, either from a direct source or reflected source) discomfort vs. Disability glare;**
  - **Brightness ratio (between task and surrounding area: causes discomfort or fatigue);**
  - **Diffusion (prevent shadows in visual field, measure light intensity directly below luminaires, compare to intensity between them, maximum 2:1)**

Light Survey Procedures

- **<u>Indirect lighting</u>: 90 - 100 % of light output directed to ceiling or above horizontal.**
- **<u>Semi-indirect lighting</u>: 60 - 90 % of light output is directed to ceiling or above horizontal.**
- **<u>General diffuse lighting</u>: 40 - 60 % of light output is directed downward.**
- **<u>Semi-direct</u>: 60 - 90 % of light output is directed downward or below horizontal.**
- **<u>Supplementary lighting</u>: additional lighting requirements are met with light sources designed to aid in task at hand.**

Ultraviolet Radiation

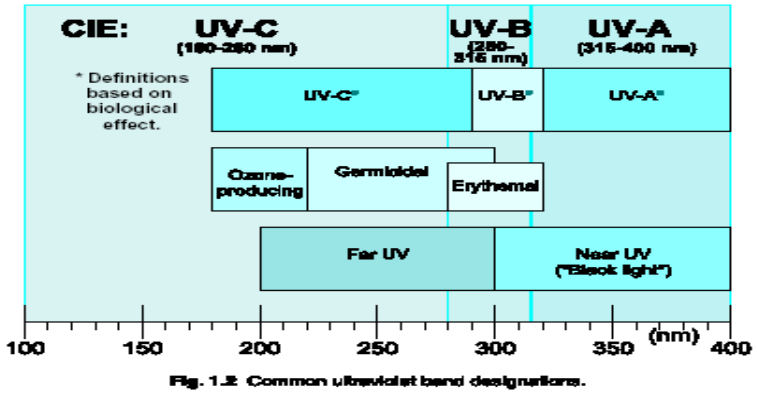


Fig. 1.2 Common ultraviolet band designations.

Sources of UV Radiation

- **Sun is major source at Earth's surface.**
- **Mercury vapor lamps.**
- **Welding activity.**
- **Germicidal lamps.**
- **"Black" lights.**
- **Fluorescent lighting.**

Effects of Exposure to UV Radiation

- **Radiation is absorbed in surface layers of skin.**
- **Eyes are also sensitive.**
- **Interaction with nucleic acids occurs at approximately 0.26 - .29 um.**
- **Effects on the skin: increased pigmentation (tanning); Burn; Skin cancer.**

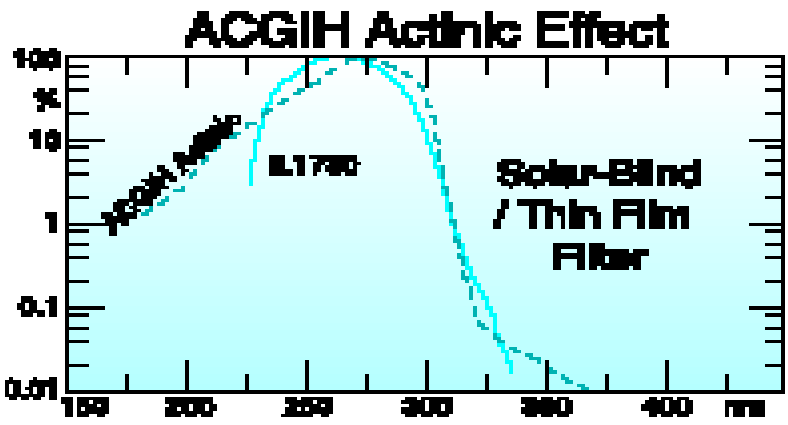
Regulation of UV Radiation

- **No PEL for UV radiation exists.**
- **TLV, intended to protect against burn and photokeratitis is available.**
- **Allowed dermal exposure is wavelength-dependent.**

Measurement of UV Exposure

- **Effects (and standards) are wavelength dependent**
  - **Meters sum exposure by wavelength**
  - **Correct for spectral effectiveness**

Regulation of UV Radiation



Measurement of UV Exposure

- **Photoelectric detectors use a phototube and photo multiplier. UV radiation interacts with a metal target, releasing electrons. The emitted electrons are counted by a photo multiplier.**
- **Photovoltaic devices work similarly to light meters. Cell sensitive to UV light releases electrons to a metal plate, setting up a potential difference that is measured.**

Infrared Radiation

- **Electromagnetic radiation in the range from .75 to 1000 um.**
- **It is perceived as a sensation of warmth: very hot objects emit IR radiation, as well as infrared lamps.**
- **Lower energy photons.**

Infrared Radiation

- **Industrial uses include.**
  - **Drying, baking of paints, varnishes and other coatings;**
  - **Heating metal parts;**
  - **Conditioning surfaces;**
  - **Dehydrating textiles, paper, leather, pottery;**
  - **Sand molds;**
  - **Other uses.**

Infrared Radiation

- **Short IR region (nearest visible light) is thought to be responsible for "glass blowers cataracts",**
- **Short wavelength infrared is considered most hazardous to the eyes: about 770 nm.**

Infrared Radiation

- **No OSHA PEL**
- **ACGIH does have a recommended TLV, for infrared lamps.**
- **Visible light is covered in the TLV, and overlaps UV TLV for persons with cataract removed.**
- **Most persons are covered by TLV including wavelengths from 400 to 1400 nm.**
- **Infrared lamps usually will produce visible as well as infrared light.**

Infrared Radiation

- **Measurement.**
  - **Long IR requires a cooled thermal sensor**
  - **Near IR can use a quantum method (up to 1100 – 1700 nm, depending on sensor)**
  - **Quantum detection will not measure long IR**

Microwaves and Radiowaves

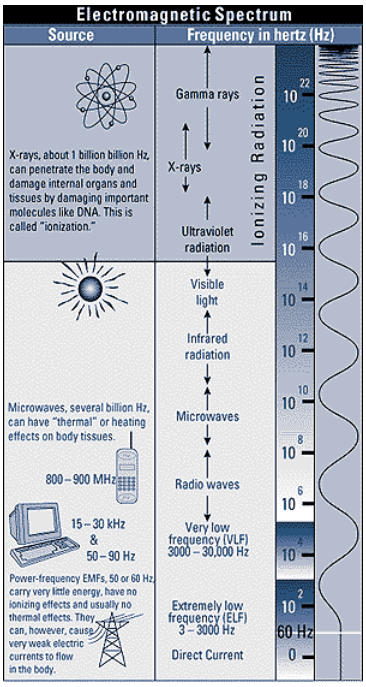
- **Effects:**
  - **heating of tissue**
  - **alteration of biochemical processes**
  - **carcinogenicity of electromagnetic radiation**
    - **data are inconclusive.**
  - **Reproductive health effects are also suspected.**

Microwaves and Radiowaves

- **Monitoring:**
  - **near field (less than 5 wavelengths).**
  - **far field.**
  - **Antennas are either thermal or electrical in design.**
  - **Measurement of near field is usually presented in field strength units**
  - **Multiply A^2/M^2 by 37.7, divide V^2/M^2 by 3770 to find power density (uw / cm^2)**

Microwaves and Radiowaves

- **Protection:**
  - **reduce duration of exposure,**
  - **introduce screening.**
  - **Properly designed and installed metal plates or mesh screens can reduce radio wave radiation.**


Electromagnetic Spectrum
Source
Frequency in hertz (Hz)
X-rays, about 1 billion billion Hz, can penetrate the body and damage internal organs and tissues by damaging important molecules like DNA. This is called "ionization."
Gamma rays
X-rays
Ultraviolet radiation
Ionizing Radiation
Visible light
Infrared radiation
Microwaves, several billion Hz, can have "thermal" or heating effects on body tissues.
Microwaves
800 – 900 MHz
Radio waves
15 – 30 kHz & 50 – 90 Hz
Very low frequency (VLF) 3000 – 30,000 Hz
Power-frequency EMFs, 50 or 60 Hz, carry very little energy, have no ionizing effects and usually no thermal effects. They can, however, cause very weak electric currents to flow in the body.
Extremely low frequency (ELF) 3 – 3000 Hz
Direct Current
60 Hz