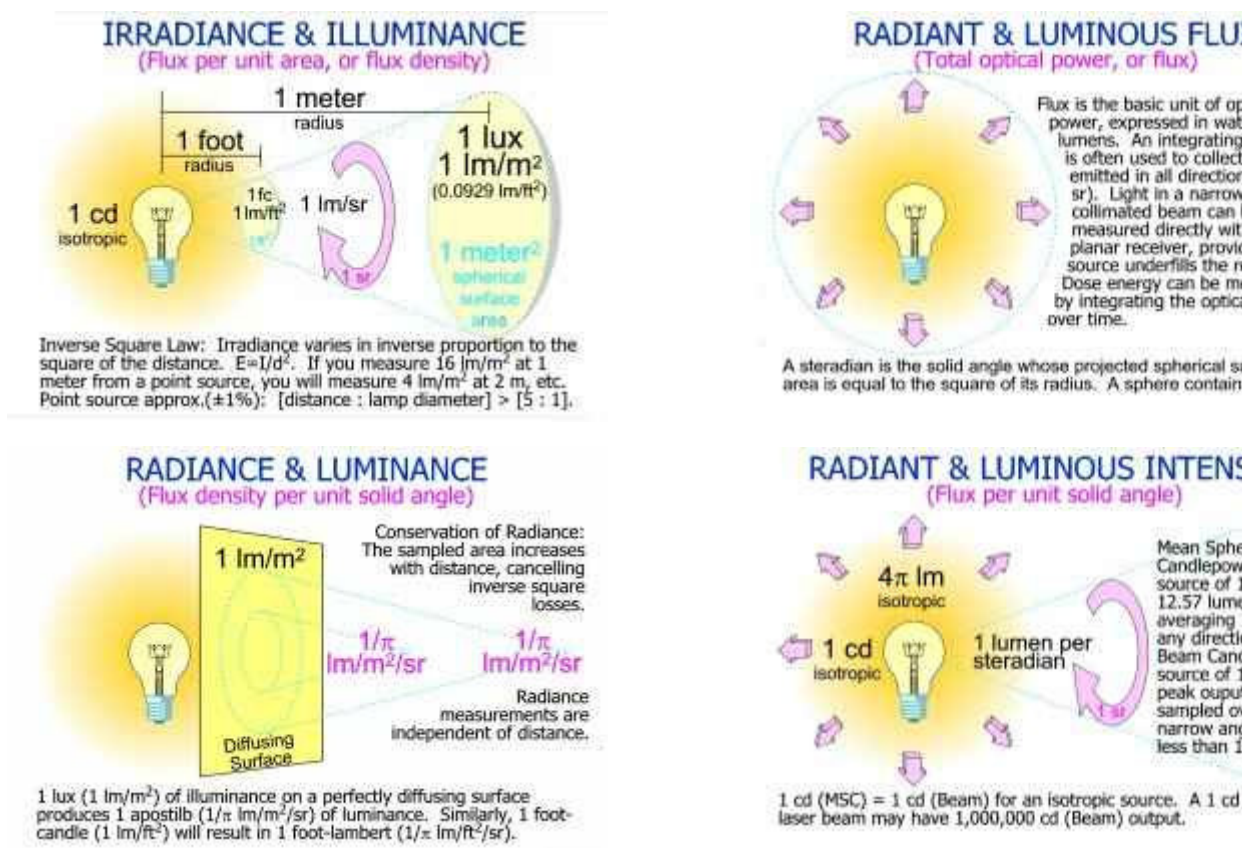


## Glossary

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### Absorptance

The dissipation of light (radiation) within a surface or medium, caused by the conversion of radiant (luminous) energy from one form of energy, usually heat, by interaction with matter. The absorption is the "missing piece", when comparing the incident and transmitted energy with the incident energy. The ratio of the total absorbed radiant or luminous flux to the incident energy is called absorptance. The standard unit of absorptance is percent (%) or a factor between 0 and 1. Absorptance can be determined from the transmission through a medium. If the %transmission of a certain wavelength is 70% then the material has an absorptance of 30%.

Absorptance.

### **Actinic**

The characteristic of radiation that indicates its capability to produce chemical change. In our industry the term is reference to UV radiation and its effects on biological systems. Actinic strips are used in UV processing to monitor sources. The color or optical density of the strip changes with the exposure dosage.

### **Ambient Light**

Ambient light is the light diffused in the environment surrounding a detector measuring the optical radiation from a source. This light contributes to the signal measured from the source. To make valid measurements, the contribution from ambient light or background must be subtracted from each measurement.

### **Aperture**

A hole through which radiant energy can pass. Angular aperture is the angle through which the most divergent rays pass through a hole or lens. The aperture of a lens is often expressed in terms of an f/#. The f/# is the ratio of the focal length of the lens to its diameter. A lens with a focal length of 100mm and a diameter of 25mm would have an aperture of f/4.

### **Attenuator**

A device which reduces the amount of energy reaching a sensor. Attenuators are typically used when the radiant energy saturates a detector. The QNDS, QNDS2 and QNDS3 filters are attenuators that reduce flux density at the detector by 100 and 1000, respectively.

### **Bandwidth**

Bandwidth describes the size of a spectral segment. A bandwidth of 10nm indicates a range of 10nm of radiation, for example, between 500nm and 510nm, 1000nm and 1010nm or an equal size segment anywhere in the spectrum.

### **Band Eliminator Filter**

A band eliminator filter allows the wavelengths above and below the filter cutoff to pass while suppressing the wavelengths in the band. These filters are also called notch filters. A 500nm band eliminator filter with a band pass of 10 nm would pass wavelengths between 495nm and 505nm.

### **Beamwidth**

The angular width of a cone of light whose apex is at the source. Beamwidth is usually defined as the angle subtended by the beam encompassing 90% of the energy.

### **Black Body**

A black body is an object that absorbs all radiant energy that hits it. When heated a black body emits a well defined spectrum which can be used in characterizing the spectral responsivity of detectors. As there is no such thing as a perfect black body, black body simulators are used for this purpose.

### **Calibration**

The process of normalizing the signal output from a detector to that of a detector defined as a standard (usually a detector defined by the National Institute of Standards and Technology (NIST) under identical illumination conditions). Calibration can also be accomplished by the use of a standard source (lamp) whose output energy at specific wavelengths and measured by a detector are traceable to the standard lamp defined by the governing standards body (NIST).

**Candela (cd) photometric measurement**

The SI unit of luminous intensity. One candela is equivalent to 1 lumen/steradian.

**Candle photometric measurement**

1 candle = 1.02 candela (cd)

**Candlepower (cp) photometric measurement**

The luminous intensity of a source expressed in candelas. A source with a luminous intensity of 10 candelas would be a 10 candlepower source.

**CCD**

A CCD (charge coupled device) is a light detector with high sensitivity primarily in the visible spectrum. CCDs are either linear or two-dimensional arrays consisting of up to millions of individual detector elements. The 2D version is used for image recording and are found in most digital cameras used in both scientific and consumer applications.

**Chromaticity**

The aspects of color associated with hue and saturation without reference to brightness.

**Chromaticity (CIE) Coordinates**

The proportion of the standard tristimulus values used in color matching. Colors are compared by their CIE X, Y, Z coordinates.

**CIE**

The CIE (Committee Internationale de l'Eclairage) is the international standards organization for illumination and colorimetry.

**Color Temperature**

Color temperature refers to the temperature, in degrees Kelvin, that a black body would have to be heated to in order to produce a color similar to the reference. A 40W incandescent bulb has a color temperature of about 2680K while daylight has a color temperature of about 5500K.

**Cosine Collector**

A cosine collector is a translucent light collector that compensates for normal blocking of radiation from a flat surface. A cosine collector samples the radiation according to the cosine law through the hemisphere above the surface. A cosine collector can be referred to as a Lambertian surface.

**Cosine Law (Lambert's cosine law)**

The flux per unit solid angle leaving or entering a surface is proportional to the cosine of the angle with respect to the surface. In a cosine collector the rays that strike the surface at an angle of  $60^\circ$  from the vertical will have a contribution (cosine of  $60^\circ$ ) that of identical rays arriving vertically.

**Cutoff Filter**

A filter that does not pass light of wavelengths shorter than the cutoff wavelength and passes a wide band of wavelengths longer than the cutoff wavelength. The cutoff wavelength is specified at some point along the transition from maximum transmission to zero transmission.

transmission. The same filter can have different cutoff wavelengths depending upon the specified % transmission may be specified as a 500nm cutoff filter with the 50% transmission point as the reference or a 485nm cutoff filter specification is the 5% transmission point, where the transmission at 485nm is 5%.

### **Dark Adaptation**

The ability of the human eye to adjust itself to low light levels.

### **Dark Signal (Current)**

The dark signal is the signal that flows in a photodetector when there is no optical radiation impinging upon it. This is created within the detector and the amplification circuits due to thermionic (temperature) effects.

### **Densitometer**

A densitometer measures the opacity or absorbance of a material. The measurement is usually expressed in AU (absorbance units) or OD (optical density).

### **Diffraction Grating**

A diffraction grating is an optical component that separates light into its constituent wavelengths. Functionally equivalent to a prism, it disperses the light into its spectrum by employing grooves to diffract the light. The angle of the diffraction is dependent on the wavelength.

### **Diffuse Reflectance**

The ratio of the incident flux to the reflected flux from a scattering surface as opposed to a highly directional or specular surface.

### **Dose**

A common, but loosely used, term for energy density, or radiant flux density, at a surface. (It is a precisely defined term: 1 Gray (Gy) = 1 J/kg, a measure of absorbed energy per unit mass). In other technologies, the term usually refers to the energy absorbed within the medium of interest, but in UV curing, it is equated only to irradiant energy density arriving at the medium of interest. [The preferred shortened term is energy density, expressed in J/cm<sup>2</sup> or mJ/cm<sup>2</sup>].

### **Dynamic Range**

The dynamic range is the ratio of the maximum measurable signal before saturation to the minimum measurable signal above noise. Typically the dynamic range is expressed in either decades (powers of 10) or bits (power of 2). A 5 decade dynamic range indicates that there is a factor of 100,000 between the maximum and minimum signals measurable with the apparatus. A dynamic range of 16 bits (264) indicates a factor 65,532 between the minimum and maximum measurable signals.

Dynamic range is also expressed in db (decibels), defined as  $10 \log_{10} (\text{maximum signal} / \text{minimum signal})$ . Five decades dynamic range is equal to 50 db.

### **Einstein**

A unit of energy equivalent to the amount of energy absorbed by one molecule of a material undergoing a photochemical reaction as determined by the Stark-Einstein law.

### **Electromagnetic Radiation**

Radiation emitted by vibrating charged particles. A combined oscillation of electric and magnetic fields that propagate through space.

space at the speed of light. The electromagnetic spectrum is theoretically infinite, includes gamma, x-ray, UV, visible light, microwaves, and radio waves.

### **Emissivity**

The ratio of an object's radiance to that emitted by a black body at the same temperature and wavelength.

### **Energy Density**

Radiant energy arriving at a surface per unit area, usually expressed in joules or millijoules per square centimeter ( $\text{mJ}/\text{cm}^2$ ). It is the time-integral of irradiance. (Other terms applied include "radiant exposure," "light dose," and "total dosage").

### **Etendue**

Also called the throughput of an optical system, it is the product of its entrance aperture and the solid angle in which it is accepted at that aperture.

### **Exitance**

Flux leaving a surface per unit area.

### **Flux**

The energy per second (power) in a light beam expressed in Watts or Joules/second. (Radiant power). In photometric measurements the luminous power is typically expressed in lumens (lm).

### **Footcandle (fc) photometric measurement**

Footcandle is a unit of measurement of illuminance (how much light is striking a point on a surface). One footcandle is equivalent to 10.764 lux.

### **Footlambert (fl) photometric measurement**

A unit of luminance equal to  $1/\pi$  candela /ft<sup>2</sup>.

### **Germicidal**

All biological organisms contain DNA. DNA is essential to reproduction. Optical radiation in the UVC range is capable of breaking the molecular bonds within DNA effectively killing microorganisms. Germicidal UV lamps are used for water treatment of foods and their containers, and air purification, especially in hospital environments.

### **Hefner Unit photometric measurement**

A unit of luminous intensity equal to 0.9 candle.

### **Illuminance photometric property**

Luminous flux incident per unit area of a surface.  $1 \text{ lumen}/\text{m}^2 = 1 \text{ lux}$ .

### **Infrared (IR)**

The invisible portion of the electromagnetic spectrum that extends from 0.75 microns to 1000 microns. Radiation in this range is used for heating, night vision, and remote sensing.

infrared (NIR) produces the sensation of heat.

### **Integrating Sphere**

A hollow sphere coated with a white diffusing coating in the interior. It is used for measuring the diffuse reflectance transmittance of objects or the total flux from a source that is completely inside.

### **Intensity**

Flux per solid angle. Radiometric measurements are made in W/sr. Photopic measurements are made in lumens/

### **Inverse Square Law**

The inverse square law correlates the relative intensity at varying distances from a point source. The relative intensity is a factor of the square root of the difference in distance. For example if at 2 meters from a source the intensity is  $4\text{W/m}^2$  at 4 meters and  $\text{W/m}^2$  at 8 meters. For extended (non-point) sources the intensity fall off approaches the law at a distance equivalent to 5 times the diameter of the source.

### **Irradiance radiometric property**

Radiant flux incident per unit area of a surface; the power incident per unit area. The radiometric unit of measure is  $\text{W/m}^2$ . The photometric units of measure are lumens/ $\text{m}^2$ , lux, phot, and footcandles.

### **Joule (J)**

The Joule is the SI unit of energy.

### **Lambertian Surface**

A surface whose emission or scattering follows Lambert's Cosine Law, in which the radiant intensity leaving a surface is proportional to the cosine of the angle from surface normal. See Cosine Collector.

### **Linearity**

The precision with which there is a direct relationship between the incident radiation and the resultant measurement point of saturation. A linearity of 1% states that the ratio of the measured value to that of the incident radiation will be within 1% from the absolute.

### **Lumen (lm) photometric measurement**

The lumen is the photometric unit of power. It is the flux emitted in a unit solid angle by a point source that has one candela of luminous intensity.

### **Luminance photometric property**

Flux density per unit solid angle.

### **Lux radiometric measurement**

S.I. unit of illuminance equal to 1 lumen per square meter.

### **Micron**

A unit of length equal to  $10^{-6}$  m. Infrared wavelengths are typically measured in microns.

### **Monochromator**

A monochromator is a device that uses a diffraction grating or prism to disperse light into a spectrum of its constituent wavelengths. The dispersive element is rotated such that only a narrow (monochromatic) band of light is permitted through a narrow aperture or slit.

### **Nano**

Prefix denoting  $10^{-9}$ . One nanowatt (nW) =  $10^{-9}$  watts.

### **Nanometer (nm)**

A unit of length equal to  $10^{-9}$  m. Abbreviated nm. Commonly used unit to define wavelength of light, particularly in visible ranges of the electromagnetic spectrum.

### **Narrow Band Filter**

A narrow band filter allows only a limited number of wavelengths to pass through it. Narrow band filters are usually specific central wavelength, a band pass indicating the range of wavelengths that will pass through it and a % transmittance limits of the band pass. A 500nm narrow band pass filter with a band pass of 10 nm with a 5% cut off will pass the between 495nm and 505nm. The transmittance above and below these wavelengths will be less than 5%.

### **Neutral Density Filter**

A filter that reduces the intensity of the light passing through it without altering the relative spectral distribution of the light. Neutral densities are given by the log base 10 of their attenuation. An attenuation of 100 gives a Neutral Density (Optical Density) of 2.

### **Nit (nt) photometric measurement**

A unit of measure of brightness (luminance) equal to one candela per square meter.

### **Noise Equivalent Irradiance (NEI)**

The radiant flux density in  $W/cm^2$  required to produce a signal equal to the inherent noise of the detection system. The irradiance at which the signal to noise ratio is 1.

### **Noise Equivalent Power (NEP)**

The radiant power, at a specified wavelength and band pass that will produce an output signal from a detector equal to the inherent noise in that detector.

### **Normal**

The normal is the axis drawn perpendicular to an illuminated surface. The normal is the reference from which reflection and refractive angles are measured. A ray with a zero degree angle of incidence arrives perpendicular to a surface. A  $90^\circ$  angle of incidence is parallel to a surface and may not strike it.

### **Notch Filter**

See band eliminator filter.

### Opacity

A measure of a material's ability to block light. It is equivalent to the reciprocal of the material's transmittance.

### Optical Chopper

A mechanical or electro optical device for passing and interrupting, at a uniform frequency, a beam of light.

### Optical Density (OD)

A measure of the transmittance  $T$  through an optical medium.  $OD = -\log_{10} T$ . An OD of 1 is equivalent to 10% transmittance. An OD filter would have a transmission of 1%.

### Peak Irradiance UV curing

The intense peak of focussed power directly under a lamp. The maximum point of the irradiance profile. Measure units ( $W/cm^2$ ).

### Phot (ph) photometric measurement

A measurement unit for illuminance. One phot = 10,000 lux (lx).

### Photodiode

A photodiode is a two electrode semiconductor device with an optical radiation sensitive junction in which the reverse current varies with the illumination. The wavelength sensitivity is a function of the materials used in the device. Silicon photodiodes are sensitive through most of the visible spectrum. InGaAs photodiodes are sensitive in the NIR region of the spectrum. Photodiodes are used for the UV region of the spectrum.

### Photodynamic Therapy

The use of optical radiation in the cure of medical maladies. Photodynamic therapy is used in the treatment of skin conditions such as psoriasis, jaundice in newborns, and more recently in the treatment of certain types of cancer.

### Photometer

A device for measuring luminous intensity or luminance. A photometer employs a photopic filter which has a bandpass matched to the human eye response. The S.I. units employed are lumens and lux.

### Photomultiplier Tube (PMT)

A photomultiplier tube is a vacuum device in which a photocathode emits electrons when exposed to light. The electrons are accelerated through electrostatic fields to metal plates where a greater number of secondary electrons are emitted. This process is repeated through several stages. This amplifies the current by many thousands.

### Photopic

Having sensitivity characteristic similar to the human eye response. A photopic filter will have a band pass between 400nm and 700nm with its highest transmission at 550nm with a spectral responsivity specified by CIE.

### Photoresist

A chemical substance which is rendered insoluble upon exposure to light. By exposing photoresist through a mask, circuits can be created by washing the unexposed areas and etching the material below. Photoresists are usually

specific regions of the UV spectrum specified as UVC, UVB, and UVA depending on the type of lamp employed for

### **Photostability**

Many chemical products both medicinal and protective coatings can degrade when exposed to light. Photostability tests are made to determine the principal wavelengths responsible for the degradation and the amount of exposure (dose) that will create a change that will be deleterious to the product's efficacy. In photostability studies the effects from the visible light must be distinguished from the UV. Typically two detectors are employed with filtration limiting each to the only one spectral region.

### **Pico (p)**

Prefix denoting  $10^{-12}$ . One pW =  $10^{-12}$  Watts.

### **Radiance radiometric measurement**

Radiant power per unit source area per solid angle.  $W/m^2/steradian$ .

### **Radiant Emittance radiometric measurement**

Radiant power emitted into a full sphere ( $4\pi$  steradian) by a unit area of a source, expressed in  $W/m^2$ . An Integrating Sphere is typically used to make this measurement.

### **Radiant Exitance radiometric measurement**

The radiant flux per unit area emitted from a source.

### **Radiometer**

A device for measuring the intensity or accumulation of radiant energy.

### **Radiometry**

The science of radiation measurement. The detection and measurement of radiant energy either at specific wavelengths or as a function of wavelength over a broad spectrum. The measurement of the interaction of light with matter, including absorption, transmission, and reflectance.

### **Ray**

The geometric representation of a light path through an optical system.

### **Reflectance**

The ratio of the reflected flux to the incident flux from a surface. In some cases the measurement may be made with the specular or diffuse component of the total reflected flux. Reflectance is expressed as a percent.

### **Relative Spatial Responsivity**

The relative spatial responsivity of a detector indicates the acceptance angle and percent of incident radiation that strikes the detector. The measurement is usually made in comparison to a perfect Lambertian surface.

### **Responsivity (spectral sensitivity)**

The response or sensitivity of any system as a function of incident wavelength. In radiometry, it is the output of a detector as a function of wavelength.

### **Saturation**

A condition wherein the radiant flux density exceeds either or the capacity of a photodetector to emit electrons in a linear relationship to the incident flux and/or the current produced by the detector exceeds the capacity of the electronic circuit to handle the current in a linear fashion.

### **Scotopic**

Relating to the wavelength responsivity of the human eye under dark adapted conditions.

### **Sensitivity**

The ratio of the output signal from a detector to the input signal. This may also be expressed as the minimum input signal which will produce an output signal that exceeds the noise level of the detector; i.e. where the S/N is greater than 1.

### **SI**

Systeme Internationale d'Unities; the international metric system of units.

### **Spectral Response**

The measure of a detector's relative sensitivity as a function of incident wavelength. A typical spectral response curve is the responsivity as a percentage at a given wavelength to wavelength of maximum responsivity.

### **Spectrometer / Spectrograph**

A device which measures the interaction between light and materials as a function of wavelength. A spectrometer is a monochromator with an integrated detector. A spectrograph does not have an exit slit, allowing a broad band of wavelengths to be measured simultaneously by means of a multi element detector or photographic plate.

### **Specular Reflectance**

Reflection from a mirror-like surface where in the coherence of the incident beam is maintained in the reflected beam as opposed to diffuse reflection wherein the reflected light is spread in all directions in a Lambertian-like manner.

### **Steradian (sr)**

The unit of solid angle subtended by an area on the surface of a sphere equal the square of the radius of the sphere. One steradian can be visualized as a conic section with a solid angle of approximately 66°.

### **Stilb (sb) photometric measurement**

A unit of luminance equal to 1 candela/cm<sup>2</sup>.

### **Talbot photometric measurement**

The SI unit of the quantity of light expressed in lumen-seconds.

### **Thermocouple Thermopile**

A device made up of dissimilar metals in which a small current is produced as a function of the difference in temperature between the junctions.

materials at the junction. Thermocouples can be used for measurement of radiation in the infrared region of the spectrum.

### **Transmittance**

The ratio of the radiant power transmitted through a material to the incident radiant power. Transmittance is usually expressed as a percent. A filter with a 50% transmittance (at a specific wavelength) will absorb half of the light incident on it and pass through it.

### **UV (ultraviolet)**

The invisible portion of the electromagnetic spectrum with wavelengths between 1nm and 400nm.

#### **UVA**

The portion of the UV spectrum covering the wavelength range between 320nm and 400nm. This spectral region is used in medical, UV curing and photolithographic applications. The earth's atmosphere (at sea level) absorbs all wavelengths shorter than 290nm. Prolonged exposure to UVA radiation will cause sunburn.

#### **UVB**

UVB is the portion of the UV spectrum that covers the wavelength range between 280nm and 320nm. UVB radiation is used in UV curing and photolithographic applications as well as in certain medical applications. Exposure to UVB lamps or electric arcs can cause severe sunburn and cause eye damage.

#### **UVC**

UVC is the portion of the UV spectrum that extends from 190nm to 280nm. UVC is usually employed in water treatment and sterilization applications. UVC is also used in UV curing and photolithography in microelectronics applications. Exposure to UVC radiation (from lamps, arcs, or lasers) can cause severe biological damage.

#### **VUV (vacuum ultraviolet)**

The VUV is the portion of the UV spectrum below 190 nm. Electromagnetic radiation below 190nm is absorbed by physical or chemical interactions requiring VUV radiation must be performed in a nitrogen purged environment and in a vacuum chamber below 160nm.

### **Visible Spectrum (VIS)**

The visible portion of the spectrum extends between 400nm and 700nm (per the CIE). It covers the wavelengths of light that the human eye can perceive.

### **Watt (W) radiometric measurement**

The Watt is a unit of power or work. One Watt corresponds to one Joule/sec.

### **Wavelength**

When electrons vibrate they produce oscillating perpendicular electric and magnetic fields. The distance between intensity maxima is defined as the wavelength. These distances for visible radiation are very small and are usually measured in unit lengths of nanometers (nm).

**POWER:**

**IRRADIANCE:**

**RADIANCE:**

**1 watt (W):**

= 0.27 lm @ 400 nm  
 = 25.9 lm @ 450 nm  
 = 220.0 lm @ 500 nm  
 = 679.0 lm @ 550 nm  
 = 683.0 lm @ 555 nm  
 = 430.0 lm @ 600 nm  
 = 73.0 lm @ 650 nm  
 = 2.78 lm @ 700 nm

**1 lumen (lm)**

=  $1.465 \times 10^{-3}$  W @ 555 nm  
 =  $7.958 \times 10^{-2}$  candela ( $4\pi$  sr)

**1 joule (J)**

= 1 watt\*second  
 =  $1 \times 10^7$  erg  
 = 0.2388 gram\*calories

**1 lm\*second**

= 1 talbot (T)  
 =  $1.464 \times 10^{-3}$  joules @ 555 nm

**1 W/cm<sup>2</sup>**

=  $1 \times 10^4$  W/m<sup>2</sup>  
 =  $6.83 \times 10^6$  lux @ 555 nm  
 =  $14.33$  g\*cal/cm<sup>2</sup>/min

**1 lm/m<sup>2</sup>**

= 1 lux  
 =  $1 \times 10^{-4}$  lm/cm<sup>2</sup>  
 =  $1 \times 10^{-4}$  phot (ph)  
 =  $9.290 \times 10^{-2}$  lm/ft<sup>2</sup>  
 =  $9.290 \times 10^{-2}$  foot-candles (fc)

**INTENSITY:****1 watt/steradian (W/sr)**

= 12.566 watts (isotropic)  
 = 683 candela @ 555 nm

**1 lumen/steradian (lm/sr)**

= 1 candela (cd)  
 = 12.566 lumens (isotropic)  
 =  $1.464 \times 10^{-3}$  W/sr @ 555 nm

**1 W/cm<sup>2</sup>/sr**

=  $6.83 \times 10^6$  lm/m<sup>2</sup>/sr @ 555 nm  
 = 683 cd/cm<sup>2</sup>@ 555 nm

**1 lm/m<sup>2</sup>/sr**

= 1 candela/m<sup>2</sup> (cd/m<sup>2</sup>)  
 = 1 nit  
 =  $1 \times 10^{-4}$  lm/cm<sup>2</sup>/sr  
 =  $1 \times 10^{-4}$  cd/cm<sup>2</sup>  
 =  $1 \times 10^{-4}$  stilb (sb)  
 =  $9.290 \times 10^{-2}$  cd/ft<sup>2</sup>  
 =  $9.290 \times 10^{-2}$  lm/ft<sup>2</sup>/sr  
 = 3.142 apostilbs (asb)  
 =  $3.142 \times 10^{-4}$  lamberts (L)  
 =  $2.919 \times 10^{-1}$  foot-lambert