Principles of Illumination Design:

Visual task, Factors affecting visual task, Modern theory of light & colour, Synthesis of Light, Additive & Subtractive synthesis of colour, Luminous flux, candela, solid angle illumination, utilization factor, Depreciation factor, MSCP, MHCP, Lens of illumination, Classification of lighting, Artificial lights sources, spectral energy distribution, Luminous efficiency, colour temperature, colour rendering.

Introduction:

Visual task is the term given to an activity requiring visual perception and located in a certain place (e.g. reading, writing, drawing, computer working).

As a body is gradually heated above room temperature, it begins to radiate energy in the surrounding medium in the form of electromagnetic waves of various wavelengths. The nature of this radiant energy depends on the temperature of the hot body.

Radiant efficiency of the luminous source is defined as the ratio of "energy radiated in the form of light" to "total energy radiated out of the hot body" and it depends on the temperature of the source.

As the temperature is increased beyond that at which the light waves were first given off, the Radiant efficiency increases, because the light energy will increase in greater proportion than the total radiated energy. When emitted light becomes white, i.e. it includes all the visible wavelengths, from extreme red to extreme violate, then a further increase in temperature produces radiations which are of wavelengths smaller than that of violate radiations. Such radiations are invisible and are known as ultra-violate-radiations. It is found that maximum radiant efficiency would occur at about 6200 °K and even then the value of this maximum efficiency would be 20%. Since this temperature is far above the highest that has yet been obtained in practice, it is obvious that the actual efficiency of all artificial sources of light i. e. those depending on temperature incandescence, is low. Light is thus a part of radiant energy that propagates as a wave motion through ether, approx. velocity being 3x108 m/sec. The wavelengths which can produce sensation of sight have a range from 4x10-5 cm to 7.5x10-5cm.

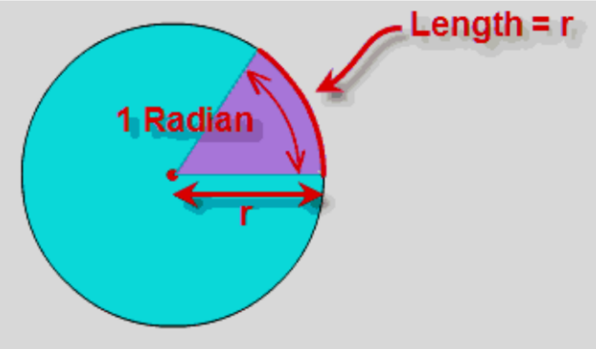
For expressing wavelength of light, another unit called Angstrom Unit (1 A.U. = 10^{-8} cm= 10^{-10} m) is used. Thus the visible radiation lies between 4000 AU to 7500 AU. Typically a wavelength of 6000 AU produce yellow colour and 4000 AU produces violate colour.

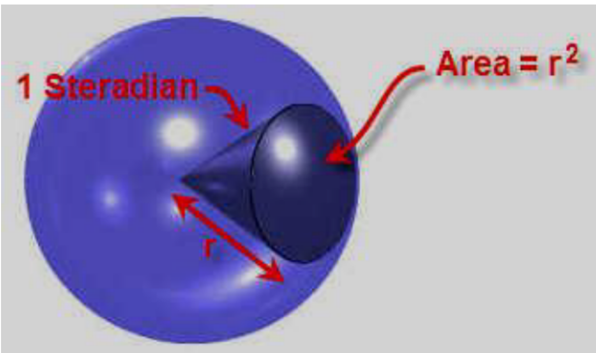
For a wave motion we have

$$frequency\ f = \frac{velocity\ v}{wavelength\ \lambda}$$

Definitions

a) **Plane angle-** A plane angle is subtended at a point and is enclosed by two straight lines lying in the same plane. In radians, plane angle is the ratio (arc/radius).





b) **Solid angle-** A solid angle (ω) is subtended at a point in space by an area and is the angle enclosed in the volume formed by an infinite number of lines lying on the surface of the volume and meeting at the point. In steradian, solid angle is the ratio (area/radius^2). It can also be defined as the angle subtended at the centre of the sphere by a part of its surface having an area equal to (radius)^2.

The solid angle subtended by a point at the center by whole of the spherical surface in all directions in **space = (area/radius^2).**

Relationship between plane angle (θ) and solid angle (ω) is given by $\omega=2\pi\,[1-\cos(\theta/2)]$

c) **Luminous flux** is the light energy radiated out per second from the body in the form of luminous light waves. It is thus the rate of energy radiation in the form of light. It is energy per second (and hence comparable to Power). Its unit is lumen. Approximate relation between lumen and electric unit of power i.e. watt is given as:

1 lumen=0.0016 watt (approx) or 1 watt=625 lumen (approx)

d) **Lumen** is defined as the luminous flux emitted in a unit solid angle by a source of one candle power. i. e. Lumen=candle power x solid angle= cp x ω.

e) **Luminous intensity (I) or Candle-power** of a point source in a given direction is the luminous flux (number of lumens) radiated out per unit solid angle. In other words, it is solid angular flux density of a source in a specified direction. **Its unit is Candela (cd) or lumens per steradian**. A source of one candela emits one lumen per steradian. Hence total flux emitted by it all-round is 4πx1=4π lumen.

An ordinary 60 - watt lamp as used for domestic lighting, when viewed from the floor, have a luminous intensity of about 70 - candle power, while a search light viewed from above the beam may have a luminous intensity of as much as a million candle power.

f) **Mean spherical candle-power (MSCP):** Generally, the luminous intensity or candle power of a source is different in different directions. The average candle-power of a source is the average value of its candle power in all the directions. Obviously, it is given by flux (in lumen) emitted in all directions in all planes divided by 4π. This average candle-power is also known as mean spherical candle-power (MSCP).

$$MSCP = \frac{total\ flux\ in\ lumens}{4\pi}$$

Mean Hemispherical candle-power (MHSCP): It is given by the total flux emitted in a hemisphere (usually the lower one) divided by the solid angle subtended at the point source by the hemisphere.

$$MHSCP = \frac{flux\ emitted\ in\ a\ hemisphere}{2\pi}$$

g) **Illumination (E) or Illuminance:** When the luminous flux falls on a surface, it is said to be illuminated. Illumination is the luminous flux received by a surface per unit area. Its unit is Lux or metre-candle or lumens per m^2.

Imagine a sphere of radius of one meter around a point source of one candela. This flux falls normally on the curved surface of the sphere which is 4π m2.Obviously, illumination at every point on the inner surface of this sphere is

$$\frac{4\pi\ lumen}{4\pi\ m^2} = 1\ lm/m^2$$

Also, Illumination = lumen/Area = *cp x ω/area*. But ω= *area/d^2*

Where, d is the distance between the area and the point where solid angle is formed.

$$\therefore Illumination = \frac{cp}{area} \times \frac{area}{d^2} = \frac{cp}{d^2}$$

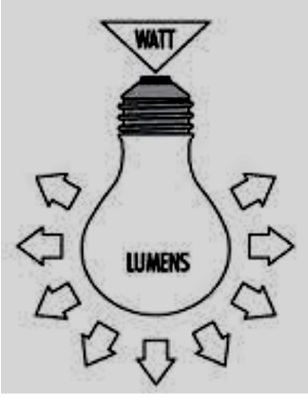
Residential		Commercial	
Kitchen	200	Classroom	300-400
Bathroom	300	Jewellery Work	700-800
Bedroom	300	Entrance Foyers	150-200
Dining	150	Office	200-300
Stairs	100	Hospital Treatment Room	400-500
Study	300	Stairs	80-100
Drawing Hall	300	Laboratories	300-400
Living	300		

Note: Industrial lighting is as per specific requirements from the consultants/ users.

h) **Brightness** of a surface is defined as the luminous intensity per unit projected area of the surface in the given direction. Unit of brightness is Lambert.

i) **Colour Rendering Index (CRI)** is a measure of the effect of light on the perceived colour of objects. A low CRI indicates that some colours may appear unnatural when illuminated by the lamp.

j) **Specific output or efficiency** of a lamp is the ratio of luminous flux to the power intake. Its unit is lumens per watt (lm/w).



Type of light source	Typical Luminous Efficiency (lm/W)
Incandescent bulb	8-18
Fluorescent Lamp	46-60
Mercury Vapour Lamp	44-57
CFL	40-70
Sodium Vapour Lamp (Low Pressure or LPSV)	101-175
Sodium Vapour Lamp (High Pressure or HPSV)	67-121
Metal Hallide	60-80
LED	30-50
Best LED	105

Design of Modern lighting:

Lighting for stores, offices, school, hospitals and house lighting. Elementary idea of special features required and minimum level of illumination required for physically handicapped and elderly in building types.