Fundamentals of light

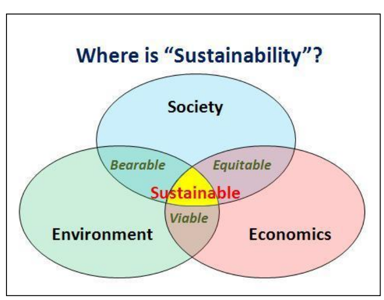
CHAPTER 1

Introduction

Environmental issues

- Limited resources .... Consumption ....

Sustainability

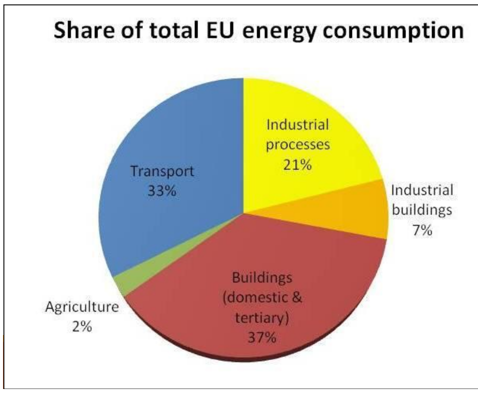


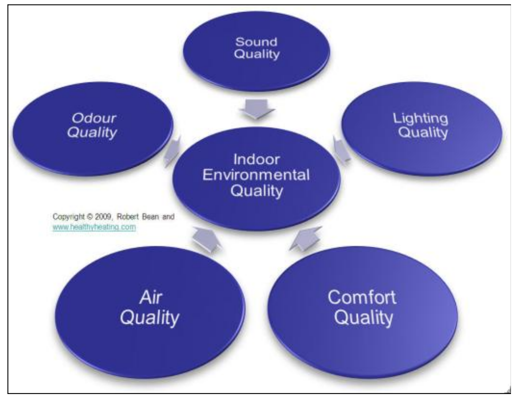
- Environmental damage will result in environmental changes (climate change, global warming, air pollution …

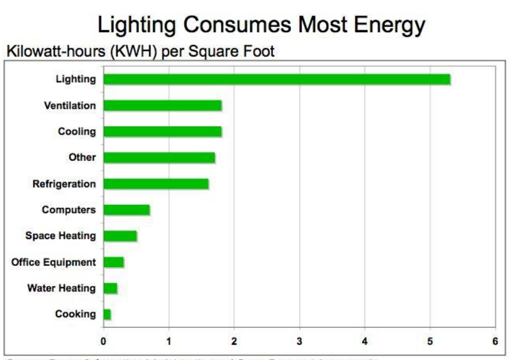
For built environment

- Indoor and outdoor environment
- Human comfort (Visual) …………….

  Efficiency (energy saving)







According to the EIA. in commercial buildings, lighting fixtures consume the most electric energy, three times the energy consumption of air conditioning.

Glare
Solar heat gain

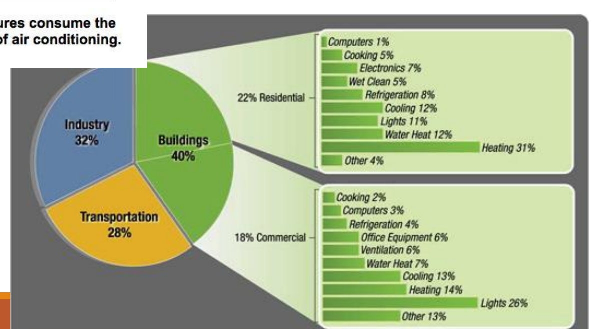
Enhancing productivity

Daylight and health

Daylight and finance

Psychologically, daylight and a view are much desired.

Visual comfort



Why studying illumination in buildings

1. Daylight—its introduction and integration with electric light
2. The interrelationship between the energy aspects of electric and daylighting, heating, and cooling
3. The effect of lighting on interior space arrangement.
4. The characteristics, means of generation, and utilization techniques of electric lighting
5. Visual needs of specific occupants and of specific tasks
6. The effects of brightness patterns on visual acuity
7. The artistic effects, and psychological effects of light and shadow
8. The use of color, both of light and of surfaces, and the effect of the illuminant source on object color
9. Physiological and psychological effects of the lighting design, particularly in spaces occupied for extended periods

Physics of light

light is a visually evaluated radiant energy

or, more simply, as a form of energy that permits us to see.

If light is considered as a wave, similar to a radio wave or an alternating-current wave, it has a frequency and a wavelength

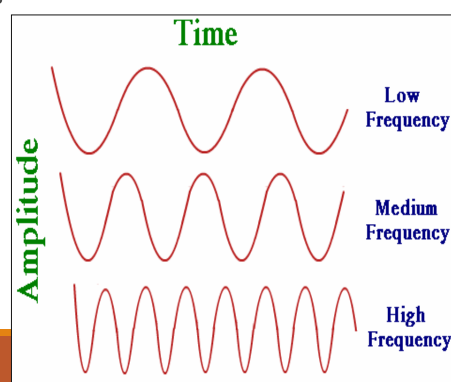
$$\lambda = \frac{v}{f} \quad \text{or} \quad f = \frac{v}{\lambda}$$

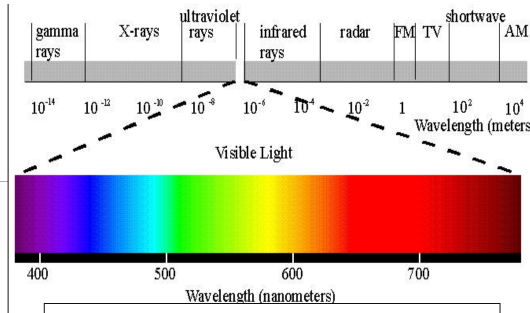
Where:

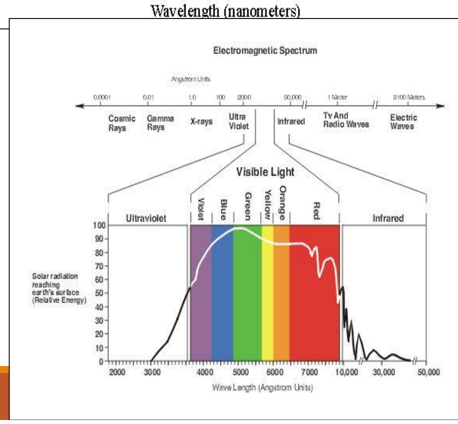
λ = wavelength in meters

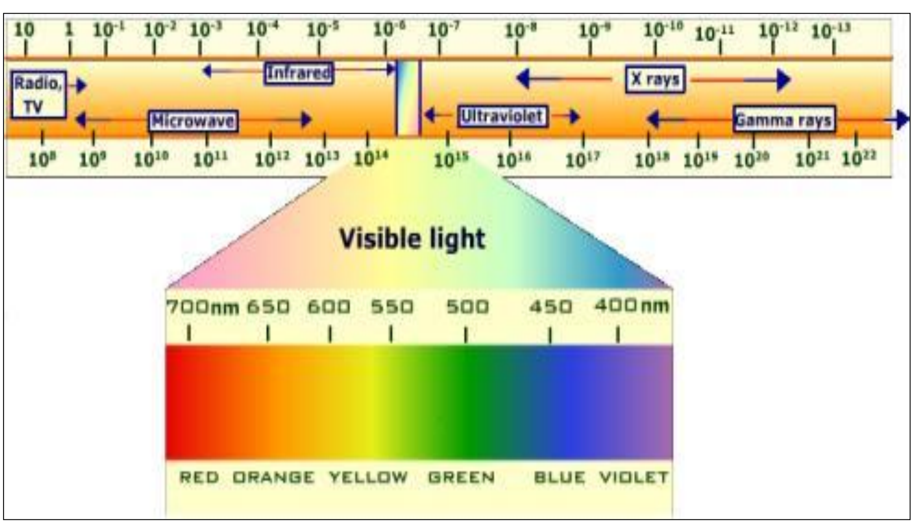
v = velocity of radio wave (speed of light)

f = frequency of radio wave (in Hz, kHz or Mhz)



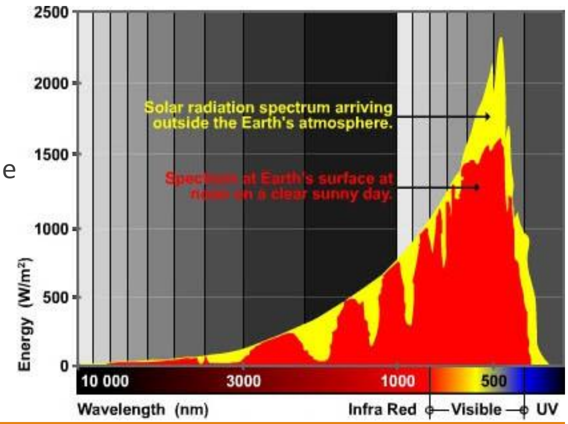

gamma rays
X-rays
ultraviolet rays
infrared rays
radar
FM
TV
shortwave
AM
Wavelength (meters)
Visible Light
400
500
600
700
Wavelength (nanometers)


Electromagnetic Spectrum
Cosmic Rays
Gamma Rays
X-rays
Ultra Violet
Infrared
Tv And Radio Waves
Electric Waves
Visible Light
Violet
Blue
Green
Yellow
Orange
Red
Ultraviolet
Infrared
Solar radiation reaching earth's surface (Relative Energy)
Wave Length (Angstrom Units)


Radio, TV
Infrared
Microwave
Ultraviolet
X rays
Gamma rays
Visible light
700nm 650 600 550 500 450 400nm
RED ORANGE YELLOW GREEN BLUE VIOLET

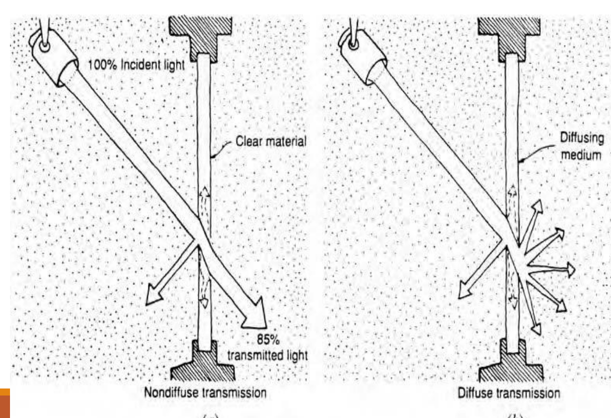
Energy - light

the majority of solar radiation occurs between the short-wave infra-red and ultra-violet portions of the electromagnetic spectrum. Ultra-violet (UV) radiation makes up a very small part of the total energy, roughly 8%- 9%. The visible range, with a wavelength of 0.35mm to 0.78mm, represents only 46%-47% of the total energy received from the sun. The final 45% of the sun's total energy is in the short-wave infrared range of 0.78mm to 5mm.



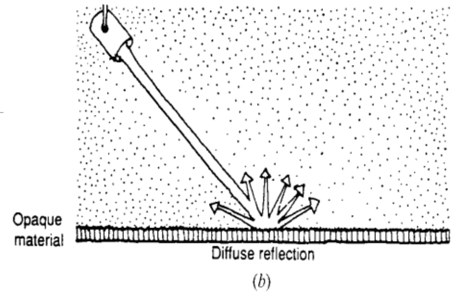
TRANSMITTANCE, ABSORPTION AND REFLECTANCE

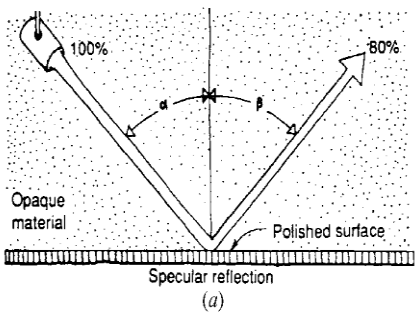
***transmittance*, *transmission factor*, and *coefficient of transmission*, is the ratio of the total transmitted light to the total incident light.**

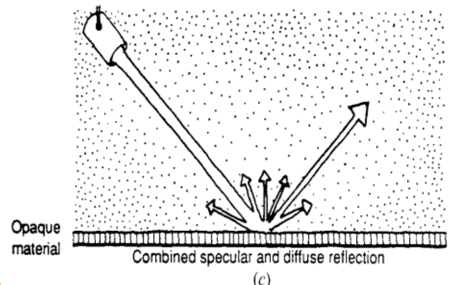


Reflectance

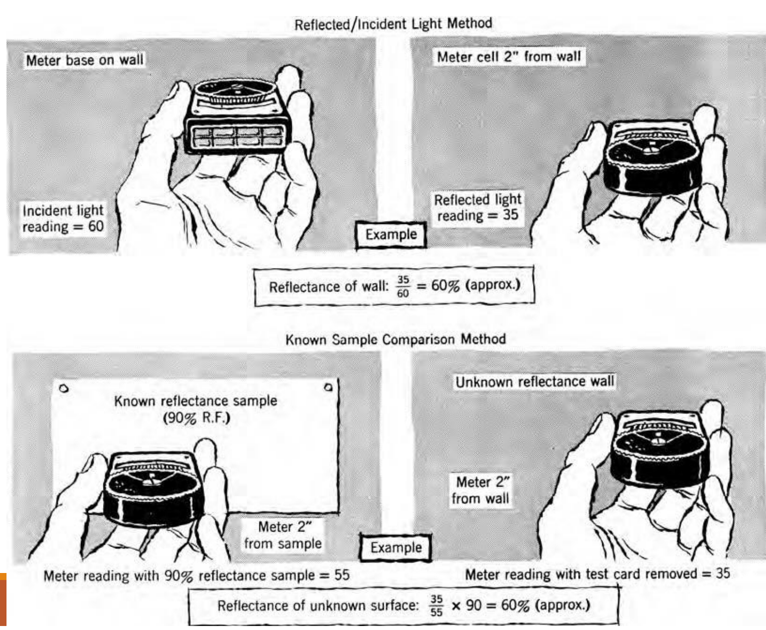
the ratio of reflected to incident light is variously called *reflectance*, *reflectance factor*, and *reflectance coefficient*







REFLECTANCE MEASUREMENTS



TERMINOLOGY AND DEFINITIONS

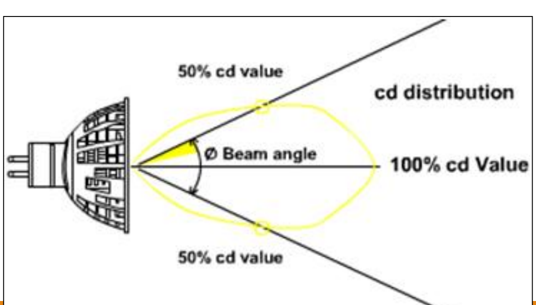
- **LUMINOUS INTENSITY (*I*)**
- **LUMINOUS FLUX (ϕ)**
- **ILLUMINANCE (E)**
- **LUMINANCE AND BRIGHTNESS (L)**

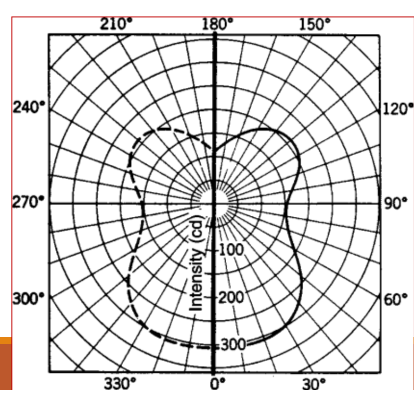
LUMINOUS INTENSITY (*I*)

The SI unit of *luminous intensity* is the candela (candlepower), abbreviated cd (cp)

and represents the force that generates the light that we see

Luminous intensity is a characteristic of the source only; it is independent of the visual sense (Radiometric unit)



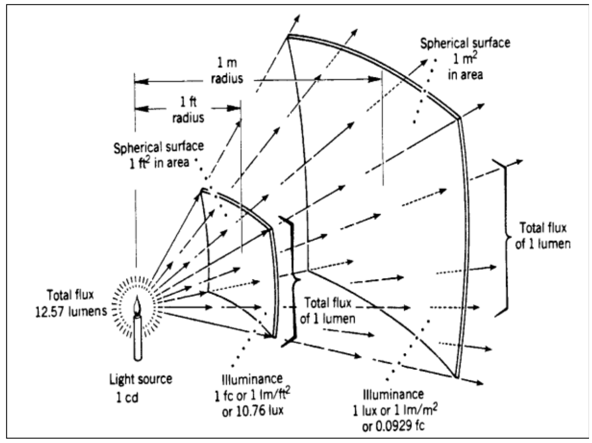


LUMINOUS FLUX (ϕ)

The unit of luminous flux, in both SI and I-P units, is the lumen (lm). (photometric unit):

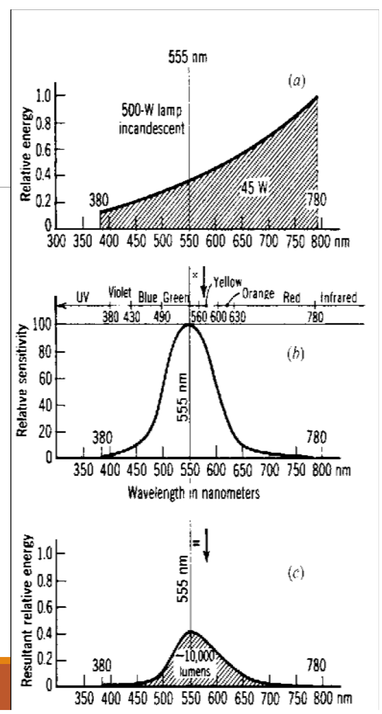
This means light power as perceived by the human eye and therefore as a function of human physiology.)

If we take a 1-cd source that radiates light equally in all directions and surround it with a transparent sphere of 1 m (ft) radius ,then *by definition* the amount of luminous energy (flux) emanating from 1 m2 (ft2) of surface on the sphere is 1 lm. Because there is 4π m2 (ft2) surface area in such a sphere, it follows that a source of 1 candela (candlepower) intensity produces 4π, or 12.57, lm.



Radiometric and photometric units

Measured radiometrically, it amounts to 45 W. However, when passed through a selective filter, which is effectively what happens when the light enters the eye, the resultant "understood" light power appears as in, and therefore can no longer be measured in watts. Instead, we use a unit of eye-perceived, or photometric, power called the *lumen*



ILLUMINANCE (E)

One lumen of luminous flux, uniformly incident on 1 m2 of area, produces an *illuminance* of 1 lux (lx)

illuminance is the density of luminous power, expressed in terms of lumens per unit area (ft2) (*footcandle* [fc]).

$$\text{lux} = \frac{\text{lumens}}{\text{square meter area}}$$

$$\text{lux} = \frac{\text{lm}}{\text{m}^2}$$

and

$$\text{footcandles} = \frac{\text{lumens}}{\text{square foot area}}$$

$$\text{fc} = \frac{\text{lm}}{\text{ft}^2}$$

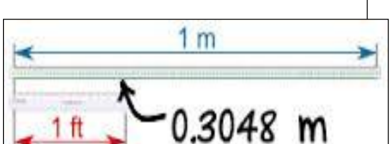
As an *approximation* (with 8% error)

$$10 \text{ lx} \approx 1 \text{ fc}$$

Convert lux to fc

10.764 lux = 1 fc

$$\frac{1 \text{ lux}}{1 \text{ FC}} = \frac{1 \text{ m}^2}{(3.28)^2 \text{ ft}^2}$$



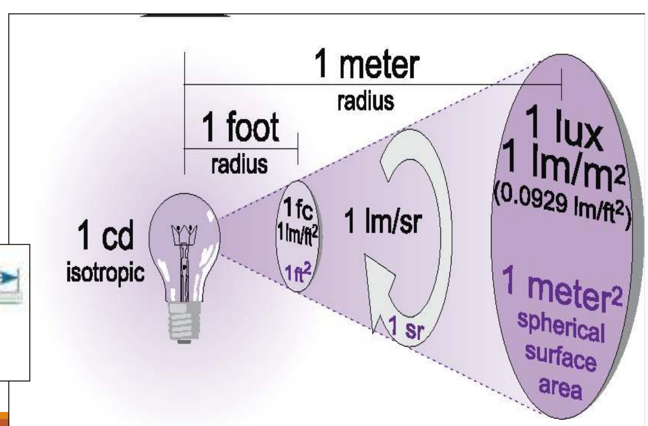


Fig. 7.4 Irradiance.

INVERSE SQUARE LAW

$$\text{lux} = \frac{\text{cd intensity}}{\text{distance}^2} \qquad (11.6)$$

$$\frac{\text{lux}_2}{\text{lux}_1} = \frac{\text{area}_1}{\text{area}_2} \qquad (11.4)$$

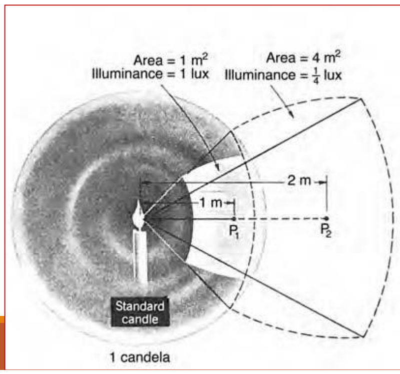
or

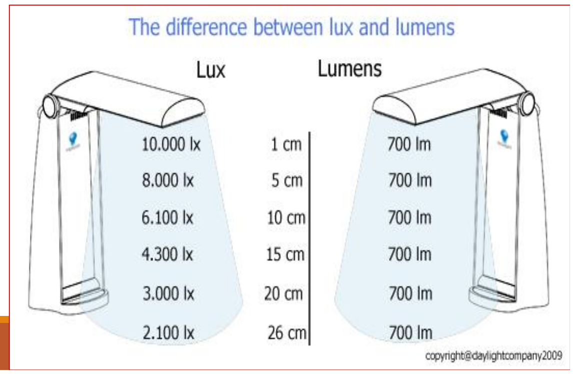
$$\text{lux}_2 = \text{lux}_1 \times \frac{\text{area}_1}{\text{area}_2}$$

therefore,

$$\text{lux}_2 = \text{lux}_1 \times \frac{4\pi r_1^2}{4\pi r_2^2} \qquad (11.5)$$

$$= \text{lux}_1 \times \frac{r_1^2}{r_2^2}$$





LUMINANCE AND BRIGHTNESS

object *luminance* (*L*), Luminance is normally defined in terms of intensity; it is the luminous intensity per unit of *apparent* (projected) area of a primary (emitting) or secondary (reflecting) light source : (cd/m²)

Brightness

An object is perceived because light coming from it enters the eye. The impression received is one of object *brightness*. This brightness sensation, however, is subjective and depends not only upon the object *luminance* (*L*), but also upon the state of adaptation of the eye

Unit	Multiply	By	To Obtain
Illuminance (*E*)	Lux	0.0929	Footcandle
	Footcandle	10.764	Lux
Luminance (*L*)	cd/m²	0.2919	Footlambert
	cd/cm²	10,000	cd/m²
	cd/in.²	1,550	cd/m²
	cd/ft²	10.76	cd/m²
	Millilambert	3.183	cd/m²
	Footlambert	3.4263	cd/m²
Intensity (*I*)	Candela	1.0	Candlepower

luminous Exitance

luminous exitance, or simply as *exitance*, describes the total luminous flux density leaving (exiting) a surface, irrespective of directivity or viewer position.

$$\text{exitance} = \frac{\text{luminous flux}}{\text{area}}$$

A surface that is a perfect diffuser, whether by emitting light diffusely or reflecting light diffusely, is known as a *Lambertian surface*.

It is fairly simple to demonstrate mathematically the luminance of such a surface equals 1/π times its exitance.

$$\text{luminance} = \frac{l}{\pi}\ (\text{exitance})$$

$$L = \frac{E \times RF}{\pi}$$

and in I-P units,

$$fL = fc \times RF$$

where

L = luminance in cd/m^2

E = illuminance in lux

RF = reflection factor

fL = luminance in foot-lamberts

fc = illuminance in footcandles (

ILLUMINANCE AND LUMINANCE MEASUREMENT

Example – 1

A 34-W, 425-mA (milliampere), 48-in. (122-cm) fluorescent tube produces 3200 lm. What is the illuminance on the floor of a 3-m2 room, assuming 60% overall efficiency and uniform illumination?

Example – 2

Luminance of a light-emitting surface.

1. Calculate the luminance of an A-19 standard inside-frosted, 100-W incandescent light bulb with a maintained output of 1700 lm. Assume(for simplicity's sake) that the bulb is spherical. An A-19 bulb has a diameter of 19/8 in. (60 mm)

2. Assume that an opal glass globe of 8 in. (200 mm) diameter and a transmittance of 35% surrounds the bulb described in step 1. Calculate the luminance of the globe. Use SI units throughout.

Example – 3

Calculate the luminance of a 34-W, T12, 4-ft white fluorescent lamp. Assume a viewing angle normal to the long axis of the lamp and that the lamp is a diffuse (Lambertian) emitter. Use SI units.

use 2770 lm. The luminous length is 4 ft (1200 mm) and the diameter is 12/8 in. (38 mm).

Example – 4

To demonstrate the usefulness of the luminance/exitance approximation, calculate the luminance, in SI units, of the page that you are now reading. Assume a uniform illuminance of 500 lx, a diffuse reflectance of 0.77, and a viewing angle normal to the page.