

ENERGY PROFILES LIMITED

# Lighting 101

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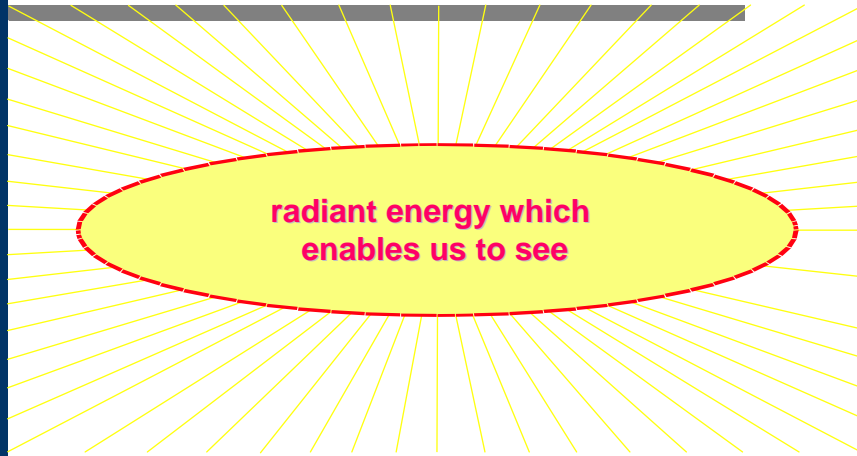
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## Outline

- Introduction to Light and Colour
- Lighting Metrics
- Lighting Terminology
- Lamps, Luminaires, Efficiency & Life
- Design Issues
- Applications

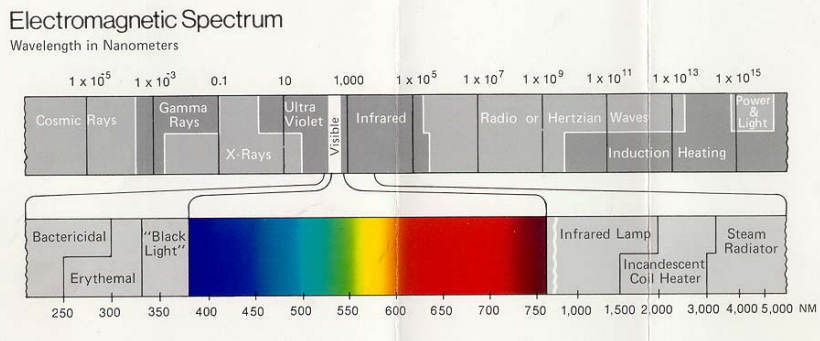


# Light is...



# Light and Colour - Electromagnetic Spectrum

The Visible Spectrum is Radiant energy between 380 and 770 nm wavelength





## Light and Colour – What We See

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- The human eye does not see light, but only reflected light
- Human perception of brightness relies on what is reflected from the surface
- Glare comes from the light source (direct glare), and may be reflected from the surface (reflected glare)
- Luminance ratios compare the brightness of different surfaces

5



## Light and Colour - Appearance

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- Colour appearance of objects depends on the colours present in the source
- Each light source emits a specific spectrum
- Each object has a specific spectral response
- Perception problems occur when these spectra differ

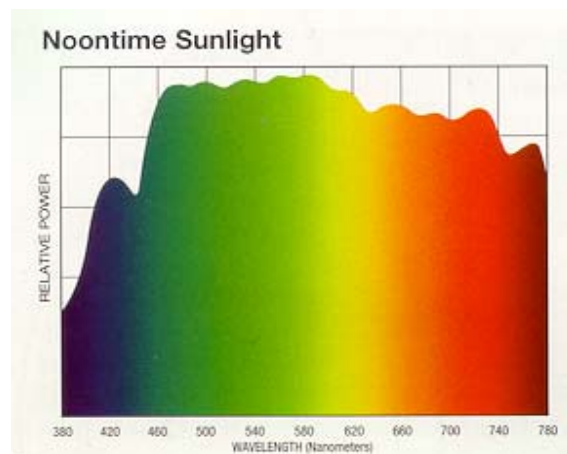
In order to see **colour** in an object, that **colour** must be emitted from the light source <sup>6</sup>

## Light and Colour - SPD

- Spectral Power Distribution Diagram
  - Represents the relative energy at all points on the spectrum of visible light
  - Makes it possible for engineers to determine the spectrum of a source
  - Depends primarily on the gas mix in the bulb, and the phosphor coating

7

## Light and Colour – SPD - Sunlight

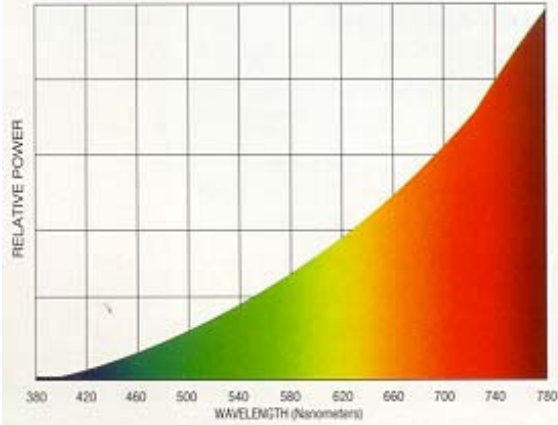


8



## Light and Colour – SPD - Incandescent

Incandescent

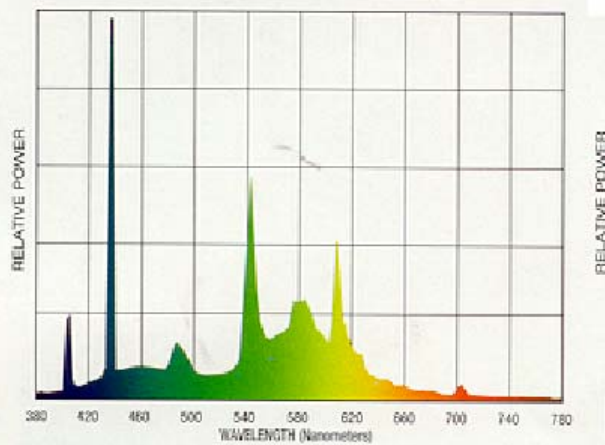


9



## Light and Colour – SPD - Fluorescent

4100K Fluorescent



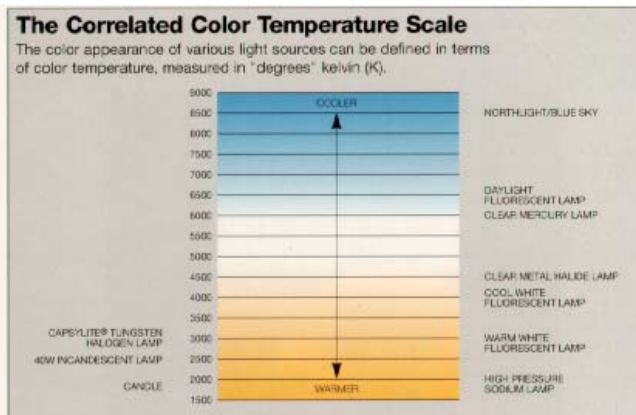
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## Light and Colour – Light Source Color Characteristics

- Color metrics
  - Correlated color temperature (CCT)
  - Color rendering index (CRI)

## Light and Colour - Correlated Colour Temperature (CCT)

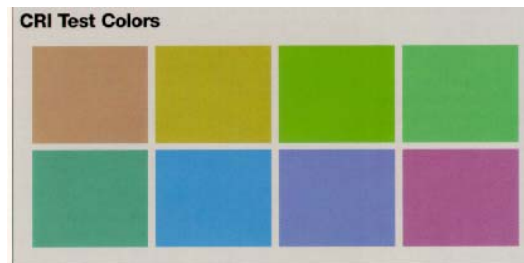
The Color Temperature of a lamp, expressed in Degrees Kelvin ( $^{\circ}\text{K}$ ), represents the 'whiteness' of the light. The higher the K value, the 'whiter' the appearance.



## Light and Colour - Colour Rendering Index (CRI)

- The CRI describes how well an object's colors are rendered by a source.
- The colors below are examined under a reference source and under the actual source. The less colour shift, the higher the CRI (0-100).
- Can only be used to compare lamps with the same CCT (Correlated Colour Temperature)

A typical cool white T12 fluorescent lamp will have a CRI of around 60.



## Lighting Metrics

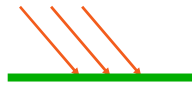
- 5 lighting metrics
  - Luminous flux
  - Illuminance\*
  - Luminous intensity
  - Luminance\*
  - Luminous exitance
    - \*These ones we will focus on



## Lighting Metrics

- Illuminance

- Amount of light that strikes a surface
- Commonly referred to as 'light level'
- Represented by the symbol, E
- Measured in footcandles, fc (IP) or lux, lx (SI)
- Important criteria for lighting design
- Used to define light quantity for a given task in a given space



15



## Lighting Metrics

- Luminance

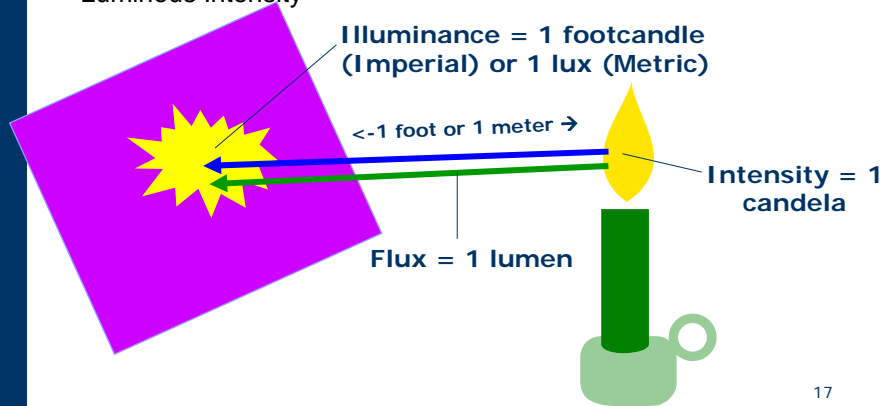
- Luminance is a function of the amount of light striking the surface (Illuminance) and the reflective property of the surface
- Intensity in the direction of an observer
- Luminance, L, is measured in candelas/sq. meter or candelas/sq. inch or sq. ft.

16

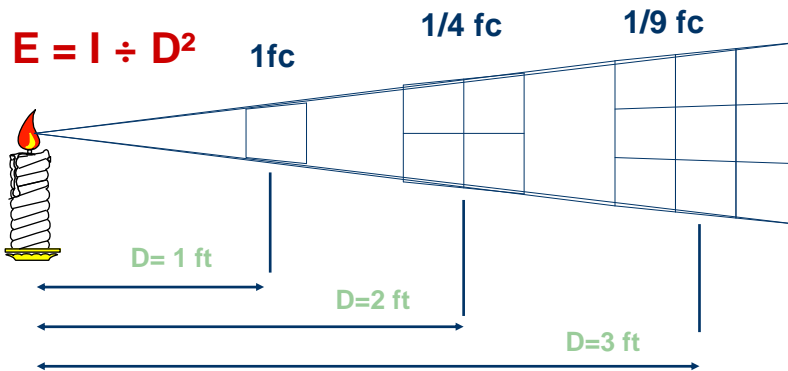


## Lighting Metrics

- Relationship between Luminous Flux, Illuminance and Luminous Intensity



## Inverse Square Law





## Terminology

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- Lamp
  - Industry term for a light source
  - Consists of a base, a bulb, and some light emitting device such as a filament
- Illuminance measurement
  - Use a measurement device commonly referred to as a light meter
  - May also be used to determine reflectance of a surface



## Terminology

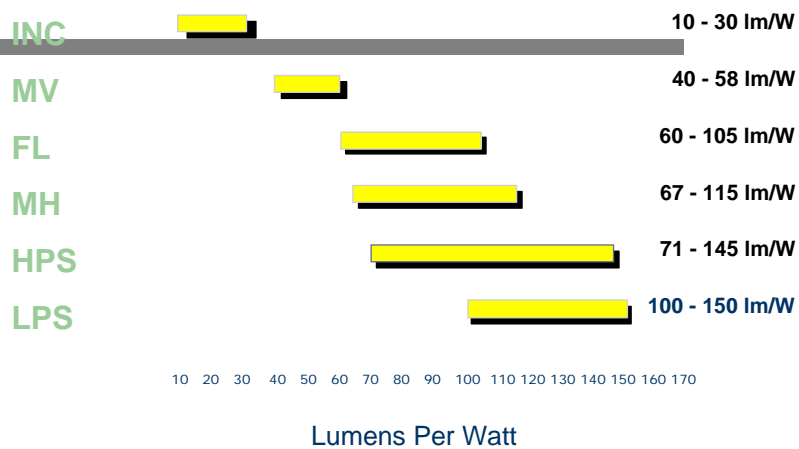
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- Luminaire
  - The term *luminaire* is used to describe a complete lighting fixture with lamp or lamps, ballast, if required, and lenses or louvers.

## Terminology

- Efficacy
  - Lamp performance or efficiency is measured in the lamp lumens output per Watt of energy input
  - Similar to miles per gallon
  - Measured in lumens per Watt (lm/W or LPW)

## Lamp Efficacy Comparison





## Lamp Efficacy & CRI Comparison

	EFFICACY	CRI
INCANDESCENT	10-20	95-100
COMPACT FL	40-60	80-83
LED	50-70	80-85
LINEAR FL	80-110	70-85
METAL HALIDE	80-90	60-85
HPS	90-110	20



## Terminology

- Efficiency
  - Luminaire efficiency is the ratio of lumens escaping the luminaire to lumens produced by the lamp
  - Example: a luminaire has two lamps producing total 6,200 lumens, and 4,960 lumens escape the luminaire
  - Luminaire efficiency is  $4,960 \div 6,200 = 80\%$
  - This means 20% of the lamp lumens are trapped within the luminaires

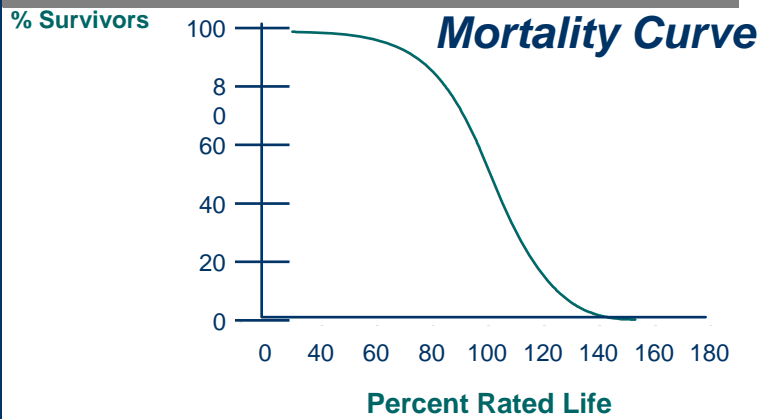


## Terminology

- Ballast
  - A device to limit the current of an arc discharge lamp, used with fluorescent and all HID light sources
  - Also provides starting voltage and power factor correction

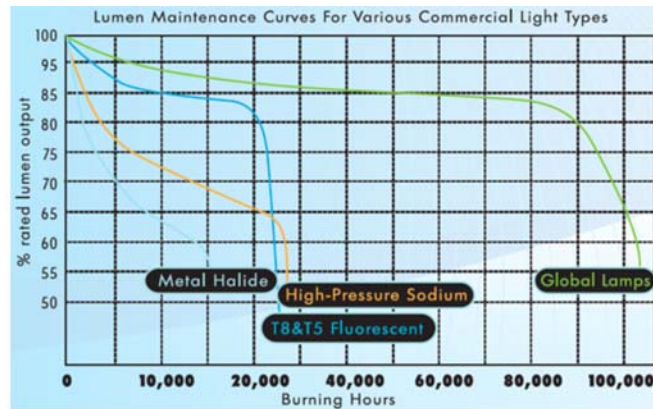


## Terminology - Lamp Mortality





## Terminology - Lumen Maintenance



## Lamp Types - Incandescent

- Inexpensive
- Readily available
- Many sizes and shapes
- Easy to control
- Spot source, good for shadows
- Wonderful color accuracy
- Extremely inefficient



## Lamp Types - CFL

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- Relatively costly
- Limited shapes and sizes
- Diffuse source, no shadows
- Hard to dim, some can be dimmed with a normal lamp dimmer
- About 5 times more efficient than incandescent



## Lamp Types – Linear Fluorescent

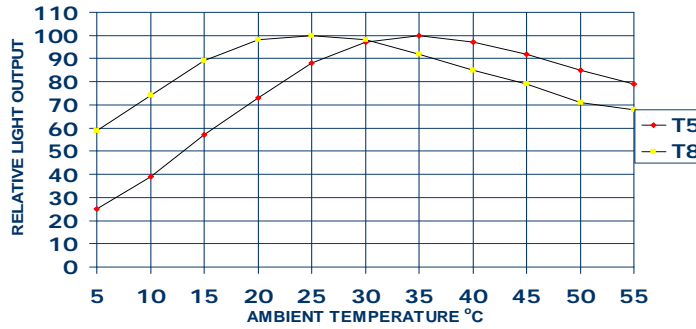
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- Fairly inexpensive
- One shape, long and thin
- Good color lamps harder to find
- Diffuse source, no shadows
- Very difficult & expensive to dim, requiring special ballasts and dimmers
- About 7-8 times more efficient than incandescent



## Lamps Types - Fluorescent

LUMEN OUTPUT VS. TEMPERATURE T8/T5

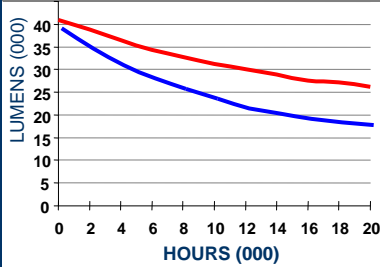


Light Sources

31



## Lamp Types - Pulse Start Metal Halide Lamps



— Pulse Start  
— Standard

Projection based on  
12K hours actual  
data.

- Pulse rated socket
- Enhanced arc tube design
- CRI 65/70
- CCT 4000/3600 K
- Improved lumen maintenance & lumen output
- Long life, improved lamp starting & colour stability
- Shorter restrike time, 5-7 minutes
- 30,000 hours life at 120 hour cycle

32



## Lamp Types - LED

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- Very expensive for the amount of light
- Selection of shapes, both linear and spot types, is improving
- Both spot & diffuse types
- Most types are expensive & difficult to dim
- About 5 times more efficient than incandescent, currently
- Ballast and lamp must be matched, and often the lamp outlasts the ballast

33



## Other Lamp Types

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- Electrodeless (Induction) Lamps
  - Very long life
  - Large lamp, difficult to control
  - Requires special fixture
  - Still quite expensive



## Luminaires - Fluorescent

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- Linear fluorescent fixtures now available with high efficiency reflectors
- Fluorescent electronic ballasts now industry standard
- Ballast selection critical for max savings
- Typical T12 EM system to T8 EB system redesign saves 40-60%
- Supersaver 28W T8 very economical

35



## Luminaires – HID/Metal Halide

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- HID electronic ballasts and electronic dimming are becoming available
- Typical MH EM system to MH EB Pulse Start system redesign saves 40%
- High CRI Ceramic MH lamps available for retail and other applications
- HID fixtures now available with high efficiency reflectors

36



## Luminaires - LED

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- LED fixtures now available for parking lot and parking garage applications
- System paybacks vary widely, initial costs very high but improving
- High CRI lamps at lower CCT values have reduced efficacy
- Lighting Designer will confirm costs and savings

37



## Lighting Controls

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Occupancy sensor (OS) controls that react to presence of people

- Reduce the 'on' times

Photocell controls (PC) that react to the amount of daylight

- Usually combined with dimming

Dimming ballasts and drivers that reduce illuminance and power consumption on a schedule, BAS or OS/PC control input

38



## IES Design Procedure

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- Design Guide Process
  - Find the activity (row) that applies
  - Determine design criteria that are very important, important & somewhat important
  - Check the definitions of these criteria
  - Check the Handbook or IES-RP documents for details
  - Check Quantity section for illuminance
  - Document the process, especially variations

39



## Design Issues - Quantity

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- Recommended Illuminance
  - 7 categories:
    - A public spaces 30 lx (3 fc)
    - B simple orientation for short visits 50 lx
    - C working spaces/simple tasks 100 lx
    - D visual tasks high contrast, large size 300 lux
    - E visual tasks med contrast, small size 500 lux
    - F visual tasks low contrast, small size 1000 lux
    - G visual tasks near threshold 3000+ lux

## Design Issues - Quality

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- Appearance of space and luminaires
- Colour appearance
- Daylight integration and control
- Direct glare
- Flicker (and strobe)
- Illuminance (horizontal)
- Illuminance (vertical)
- Intrinsic material characteristics

41

## Design Issues - Quality

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- Light distribution on surfaces
- Light distribution on task plane
- Light pollution/trespass
- Luminaire noise
- Luminance of room surfaces
- Modeling of faces or objects
- Peripheral detection
- Points of interest
- Reflected glare
- Shadows
- Source/task/eye geometry
- Sparkle/desirable reflected highlights
- Special considerations
- Surface characteristics
- System control and flexibility

42



## Applications - Office Spaces



43



## Applications - Office Spaces



44



## Applications - Office Spaces

- VDT workstations
- Other office spaces
- Critical Issues
  - Appearance of space & luminaires
  - Daylighting integration & control
  - Luminances of room surfaces
  - Reflected glare
  - Source/task/eye geometry
  - Vertical illuminance



## Applications - Industrial Facilities





## Applications - Industrial Facilities

- Critical Issues

- All design issues are critical, except those related to aesthetics, due to the diversity of lighting situations
- Quality in the manufacturing process
- Productivity of the manufacturing process
- Luminance
- Illuminance
- Luminaires



## The True Cost of Light

$$\text{Cost of light} = \frac{1}{\text{lumens}} \left\{ \frac{\text{lamp cost} + \text{labor cost}}{\text{lifetime}} \right\} + \left\{ \text{power} \times \text{energy cost} \right\}$$



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## Contact Information

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