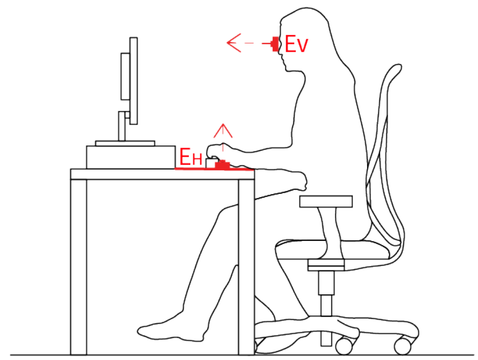
# More about lighting

## Measuring light

**Illuminance (E)** is the amount of luminous flux incident on a surface [51], and is measured in lumens per square meter (lux) or lumens per square foot (footcandle). One footcandle is equal to approximately 11 lux. Lighting designs are concerned with two types of illuminance values:

Direction of measuring horizontal illuminance ($E_H$) (light received on a workplane)

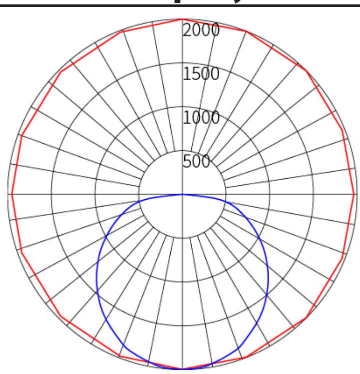



Direction of measuring vertical illuminance ($E_V$) (light received at the eye)

**Horizontal illuminance ($E_H$)** is the amount of light falling on a horizontal surface such as a table desk, measured in lux or footcandles. Appropriate $E_H$ levels are crucial for the visual system and visual task performance. Measurements of $E_H$ should be made by placing an illuminance meter flat on a horizontal surface, at the desired location.

**Vertical illuminance ($E_V$)** is light that is received at a vertical surface. To measure vertical illuminance for circadian stimulation, hold the illuminance meter vertically, with the sensor oriented in the same direction as the eye.

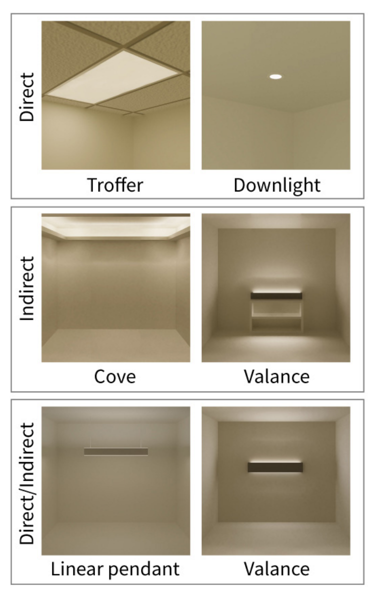
## Lumen output, beam distribution, and position of fixture



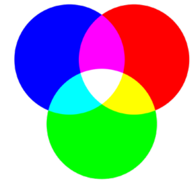

*Intensity distribution example- Trofer*

When trying to achieve CS targets in a circadian design, being mindful of a few lighting characteristics can be beneficial to meet the targets. First, the lumen output will indicate a fixture's total light output in all directions. A luminaire's distribution and intensity ultimately determines the amount of light that reaches the eye. The red curve in the figure at left indicates the shape and intensity of light when viewing the fixture from above. The blue curve indicates the shape and intensity of light that is distributed into the space. This diagram represents the "troffer" luminaire shown at right; wide distributions such as this spread the light over a wider area. A luminaire that focuses light in a small area (such as a downlight)will have a candlepower distribution curve with a narrower blue curve.

The position and location of fixtures can also change how much light reaches the eye. The terms "direct" and "indirect" indicate in which direction a light fixture projects light. As shown at right, direct fixtures are mounted at the ceiling and send light downward into the space (e.g., troffer, downlight, and recessed linear fixtures). To reduce glare from direct view of the source, lighting fixtures can be hidden in the architecture or fixture housing. Luminaires aiming light upwards are considered "indirect" lighting. Coves and wall valances are indirect lighting that hide fixtures to gently illuminate by bouncing light off the ceiling or walls. Some fixtures can provide both direct (task) illumination as well as indirect (ambient) lighting. An example would be a direct/indirect linear pendant or wall mounted valance. To achieve CS targets, consider where light is needed and what types of fixtures can achieve this.

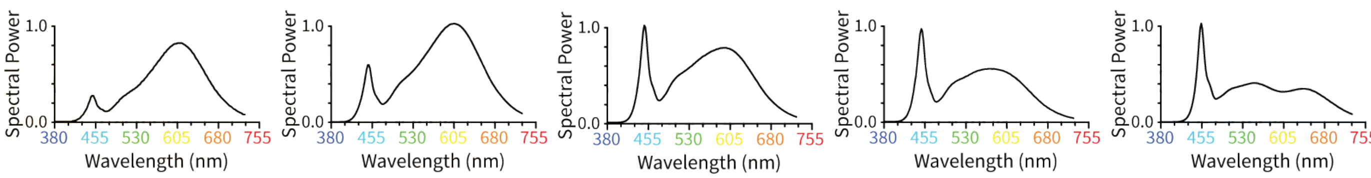


## Correlated color temperature (CCT)- Ranges of white light

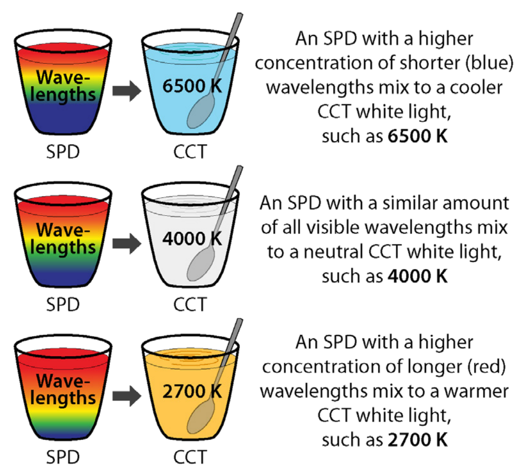


Perception of color results from the interplay between light (380–780 nm) and the retina's cone photoreceptors. What is commonly referred to as "white light" — whether "soft," "cool," or "daylight" — is actually composed of a mixture of short, medium, and long wavelengths that can be roughly classified as resembling the colors blue, green, and red, respectively (see figure). When mixed, white light is created and classified as correlated color temperature (CCT) and expressed in units of kelvin (K), ranging from the slightly reddish-yellow appearance of 2700 K (warmer white) to the sky-bluish appearance of 6500 K (cooler white). Generally speaking, warm light sources are those with CCTs < 3500 K and cool light sources are those with CCTs > 5000 K. The CCT and light output both have an impact on CS, as well as appearance and character of a space (see examples below).

| Warmer white | Warm white | Neutral white | Cool white | Cooler white |
|---|---|---|---|---|
| 2700 K | 3000 K | 4000 K | 5000 K | 6500 K |




**SPD, or spectral power distribution** graphs the relative amount of energy each wavelength has in a light source. Each light source is made up of a combination of wavelengths (x-axis), ranging in strength, which is indicated by relative spectral power (y-axis). With white light being a combination of the spectral power of the many wavelengths, it is possible for many SPDs to be classified as the same CCT. SPD curves with a similar trend that appear to be the same tint will can be classified under the same CCT, but can possess different qualities that can affect outcomes such as CS. With this being the case, it is important to use the correct SPD of sources in a design to determine its CS contribution more accurately. The warm-white 2700 K shows a larger area of contribution from the longer wavelengths, and less contribution from the shorter wavelengths making it appear to have a yellower tint. Inversely, a cool-white 6500 K shows a greater peak in the shorter wavelengths, and a smaller area of long-wavelength contribution making it appear to have a bluer tint. In lighting designs, a static or tunable CCT approach can be used. A **static CCT system** in circadian design refers to using a single CCT that dims throughout the day to achieve vertical illuminance to reach CS targets. A **dynamic CCT system** refers to using multiple CCTs that can also dim. Cooler CCTs will generally reach a CS greater than 0.3 at lower light levels (compared to warm CCTs) which can be desired in some solutions that need lower horizontal light levels for visibility or energy savings. Creating a dynamic environment by changing the color temperature of the lighting in the space and/or dimming the light output throughout the day will provide a robust schedule that is beneficial for the circadian system to synchronize to the solar day.



## References

[50] Purves D, Augustine GJ, Fitzpatrick D, Hall WC, LaMantia A-S, McNamara JO, Williams SM (2004) *Neuroscience*, Sinauer Associates, Sunderland, MA, US.