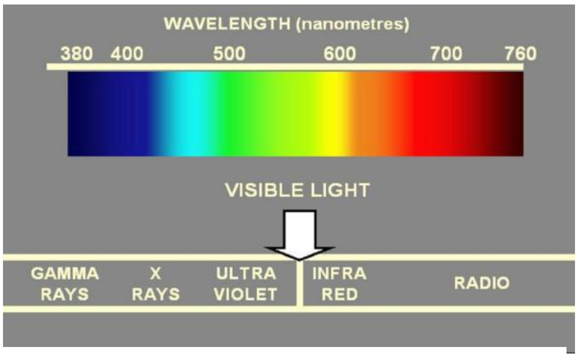
SP Ratios and Mesopic Vision

Mesopic Vision

Mesopic vision is becoming a topic of interest, especially in terms of energy saving for outdoor lighting applications. And a common indicator of mesopic effectiveness for a lighting solution is the S/P ratio. But what is mesopic vision, why is it important and what is an S/P ratio?

<u>What is mesopic vision?</u>

We are all used to talking about light and lighting, but what is light? Light is a small part of the electromagnetic spectrum which also contains a lot of other non-visible emissions such as radio waves and X rays. What makes light special is the eye. The eye is a detector, similar to a luminance meter, which is sensitive to electromagnetic emissions with wavelengths between 380 – 760 nm. So how we perceive and measure light is based upon how the eye responds to light

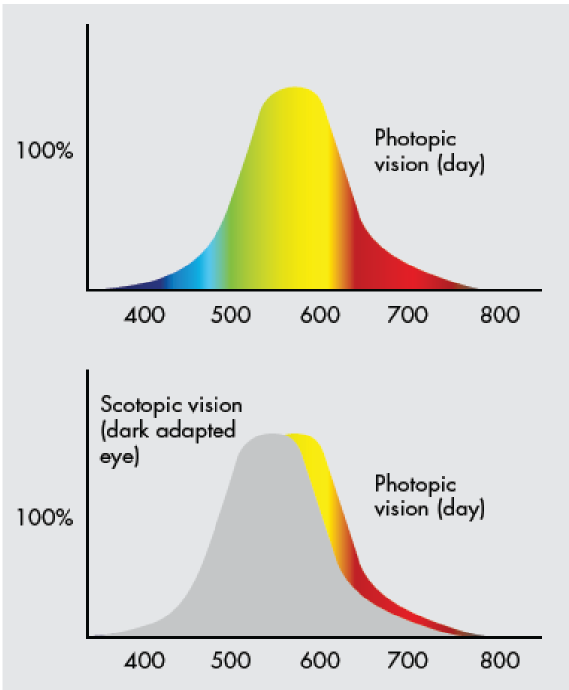


The electromagnetic spectrum

However the eye does not see all wavelengths equally. The response of the eye to different wavelengths has been measured and this has resulted in standard response curves being produced. During daylight hours we have photopic vision which allows us to see colours and fine detail.

However as the general levels of light decrease the eye adapts to the lower light levels and our ability to see colour and fine detail reduces until we can only see shades of grey. Vision at this lower level of light is called scotopic
vision.

As can be seen from the curves shown our eye moves from photopic to scotopic vision with the peak sensitivity moving from yellow towards green, and the entire curve moves towards the blue end of the spectrum. The problem is this does not happen in one step, between the photopic and scotopic response curves are many intermediate curves as the eye slowly moves between photopic and scotopic conditions. The area between photopic vision and scotopic vision is termed mesopic vision.



Photopic and Scotopic curves

Since the eye does not see illuminance but luminance the relative levels defining the shift between photopic, mesopic and scotopic vision are also defined in terms of luminance (cd/m²). Photopic vision occurs above approximately 10 cd/m², scotopic vision occurs below approximately 10^{-2} cd/m², which means the mesopic region is approximately between 10^{-2} – 10 cd/m².

Why is mesopic vision important?
If we look at the levels that define photopic, mesopic and scotopic vision we can see that during daylight hours we operate in photopic conditions. However conditions for scotopic vision are closer to those under moonlight. This means that in urban areas at night we are generally in the mesopic region of vision.

But the response curve of the eye is replicated in the equipment we use to measure light. When we use a standard illuminance meter we measure lux, the spectral power of light adjusted by the **photopic** response curve of the eye. This means that due to the eye response shifting towards the blue end of the spectrum under mesopic or scotopic conditions, we are over-estimating the contribution from higher wavelengths (red) and under-estimating the contribution from shorter wavelengths (blue). In practice our measurements no longer reflect what the eye sees.

If we could correctly measure what the eye sees under the actual conditions, instead of what the eye would see under photopic conditions, we would frequently find we are over-lighting areas due to incorrect measurements penalising mesopic efficient light sources. Therefore we are using excess energy that is not needed.

What is an S/P ratio?
This all means that a lamp that efficiently produces mesopic lumens should have a higher quantity of shorter wavelength light. However there is no practical method to measure mesopic lumens as any value would only be relevant for a specific quantity of ambient light and as this varies so will the eye response curve until we reach the steady-state conditions of photopic or scotopic vision. So the fixed points we can effectively characterise are the eye response curves for photopic and scotopic conditions.

A method to indicate how good a light source will be under photopic, mesopic and scotopic conditions is the S/P ratio, which is the scotopic lamp lumens divided by the photopic lamp lumens. If this ratio is equal to 1 the lamp performs equally under photopic, mesopic and scotopic conditions, and the reading on your illuminance meter will also be correct for all of these conditions. A value greater than 1 indicates that the lamp produces more scotopic lumens than photopic lumens, and your meter will under-estimate the scotopic illuminance levels. Conversely a value less than 1 indicates that the lamp produces more photopic lumens than scotopic lumens and your meter will over-estimate the scotopic illuminance levels.

Some representative S/P ratios are given in the table below. (note these are generic and in practice the values for the specific lamp should be used).

Light Source	**S/P ratio**
Incandescent	1.36
Fluorescent (3500K)	1.36
Fluorescent (5000K)	1.97
Metal Halide (warm white)	1.20
Metal Halide (daylight)	2.40
High Pressure Sodium	0.65
Low Pressure Sodium	0.25
LED (3500K)	1.39
LED (6000K)	2.18

The table implies that the sodium light sources will in reality under light a space whilst the white light sources will in reality over light a space when calculating using photopic lamp lumens or measuring using a photopic illuminance meter. This in turn means that for the white light sources fewer luminaires or luminaires containing lower power lamps could be used to achieve the recommended lighting levels in mesopic conditions.

Practical application of the S/P ratio

Whilst application of the S/P ratio presents us with possible energy savings by reducing the light levels necessary for lamps with a high S/P ratio we should remember that currently the majority of lighting standards do not make any allowance for this effect and therefore lighting design should be to photopic levels as currently practised now. The only exception is with the UK road lighting standard "BS 5489-1:2013 Code of practice for the design of road lighting Part 1: Lighting of roads and public amenity areas". (It is important to note that the European road lighting standard EN 13201 does not take any consideration of S/P ratios and they cannot be used).

BS 5489-1:2013 contains table A.7 (shown below) that allows the relaxation of required illuminance design levels depending upon the S/P ratio and Ra of the lamp.

Table A.7 **Variation of maintained lighting level with S/P ratio of light source**

Values in lux

Lighting class	Benchmark (e.g. $R_a < 60$ or when S/P ratio of light source is not known or specified)		S/P ratio = 1.2 and $R_a \geq 60$ (e.g. some types of warm white lamp such as metal halide)		S/P ratio = 2 and $R_a \geq 60$ (e.g. some types of cool white compact fluorescent or LED)	
	$\bar{E}$	E_{min}	$\bar{E}$	E_{min}	$\bar{E}$	E_{min}
P1 or S1	15.0	3.0	13.4	2.7	12.3	2.5
P2 or S2	10.0	2.0	8.6	1.7	7.7	1.5
P3 or S3	7.5	1.5	6.3	1.3	5.5	1.1
P4 or S4	5.0	1.0	4.0	0.8	3.4	0.7
P5 or S5	3.0	0.6	2.2	0.4	1.8	0.4
P6 or S6	2.0	0.4	1.4	0.4	1.1	0.4

So if we designed a solution to lighting class S1 using the previously discussed high pressure sodium lamp (S/P=0.65) and metal halide lamp (S/P=1.55) our required design levels would be

High Pressure Sodium lamp $\bar{E}$ =15.0 lx; E_{min}=3.0 lx

Metal Halide lamp $\bar{E}$ =13.4 lx; E_{min}=2.7 lx

Note that by reducing the required photopic illuminance levels based upon the S/P ratio this table accounts for the effects of mesopic vision and therefore no other reductions based upon the S/P ratio should be made.

It is important to understand that unless specifically allowed for within a standard or design specification adjustment of the lighting requirements based upon the S/P ratio should not be performed.

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