

## The visible spectrum

### Table of Contents

Uncover through science what makes black color the way it is and how researchers are developing the real pure version of black

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Newton demonstrated that colour is a quality of light. To understand colour, therefore, it is necessary to know something about light. As a form of electromagnetic radiation, light has properties in common with both waves and particles. It can be thought of as a stream of minute energy packets radiated at varying frequencies in a wave motion. Any given beam of light has specific values of frequency, wavelength, and energy associated with it. Frequency, which is the number of waves passing a fixed point in space in a unit of time, is commonly expressed in units of hertz ( $1 \text{ Hz} = 1 \text{ cycle per second}$ ). Wavelength is the distance between corresponding points of two consecutive waves and is often expressed in units of metres—for instance, nanometres ( $1 \text{ nm} = 10^{-9} \text{ metre}$ ). The energy of a light beam can be compared to that possessed by a small particle moving at the velocity of light, except that no particle having a rest mass could move at such a velocity. The name *photon*, used for the smallest quantity of light of any given wavelength, is meant to encompass this duality, including both the wave and particle characteristics inherent in wave mechanics and quantum mechanics. The energy of a photon is often expressed in units of electron volts ( $1 \text{ eV} = 1.602 \times 10^{-12} \text{ erg}$ ); it is directly proportional to frequency and inversely proportional to wavelength.

Light is not the only type of electromagnetic radiation—it is, in fact, only a small segment of the total electromagnetic spectrum—but it is the one form the eye can perceive.

Wavelengths of light range from about 400 nm at the violet end of the spectrum to 700 nm at the red end (*see table*). (The limits of the visible spectrum are not sharply defined but vary among individuals; there is some extended visibility for high-intensity light.) At shorter wavelengths the electromagnetic spectrum extends to the ultraviolet radiation region and continues through X-rays, gamma rays, and cosmic rays. Just beyond the red end of the spectrum are the longer wave infrared radiation rays (which can be felt as heat), microwaves, and radio waves. Radiation of a single frequency is

called monochromatic. When this frequency falls in the range of the visible spectrum, the colour perception produced is that of a saturated hue.

Range of the visible spectrum

colour*	wavelength (nm)	frequency (10 <sup>14</sup> Hz)	energy (eV)
red (limit)	700	4.29	1.77
red	650	4.62	1.91
orange	600	5.00	2.06
yellow	580	5.16	2.14
green	550	5.45	2.25
cyan	500	5.99	2.48
blue	450	6.66	2.75
violet (limit)	400	7.50	3.10

\*Typical values only.