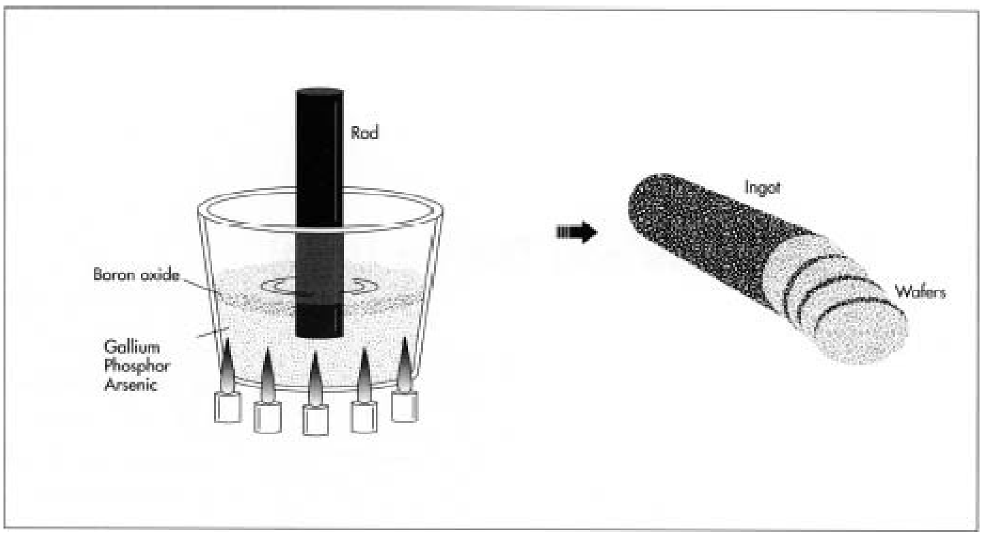
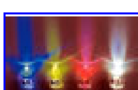
LED: TECHNICAL INFORMATION



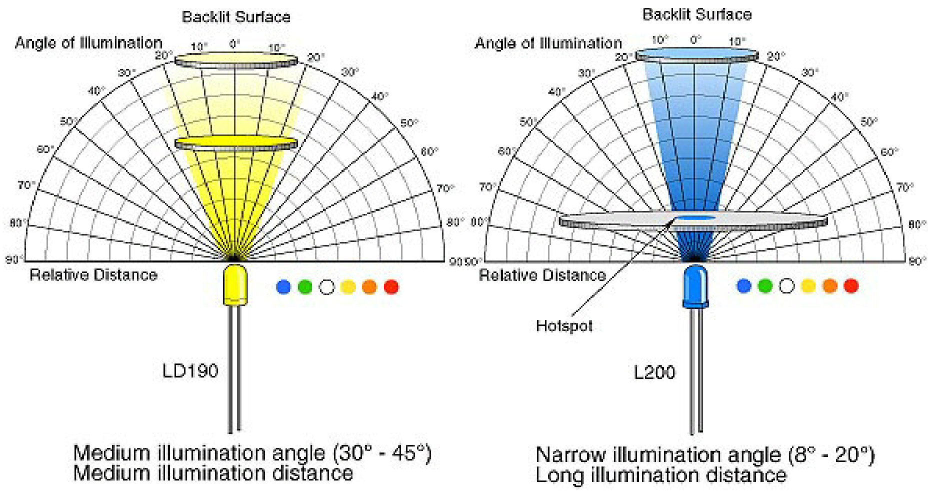
To make the semiconductor wafers, gallium, arsenic, and/or phosphor are first mixed together in a chamber and forced into a solution. To keep them from escaping into the pressurized gas in the chamber, they are often covered with a layer of liquid boron oxide. Next, a rod is dipped into the solution and pulled out slowly. The solution cools and crystallizes on the end of the rod as it is lifted out of the chamber, forming a long, cylindrical crystal ingot. The ingot is then sliced into wafers.



Technical LED's *LED Color Chart*

	Wavelength (nm)	Color Name	Fwd Voltage (Vf @ 20ma)	Intensity 5mm LEDs	Viewing Angle	LED Dye Material
	940	Infrared	1.5	16mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide

	880	Infrared	1.7	18mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
	850	Infrared	1.7	26mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Aluminum Arsenide
	660	Ultra Red	1.8	2000mcd @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Aluminum Arsenide
	635	High Eff. Red	2.0	200mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
	633	Super Red	2.2	3500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	620	Super Orange	2.2	4500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	612	Super Orange	2.2	6500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	605	Orange	2.1	160mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
	595	Super Yellow	2.2	5500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	592	Super Pure Yellow	2.1	7000mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	585	Yellow	2.1	100mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
	4500K	"Incan-descent" White	3.6	2000mcd @20mA	20°	SiC/GaN -- Silicon Carbide/Gallium Nitride
	6500K	Pale White	3.6	4000mcd @20mA	20°	SiC/GaN -- Silicon Carbide/Gallium Nitride
	8000K	Cool White	3.6	6000mcd @20mA	20°	SiC/GaN - Silicon Carbide / Gallium Nitride
	574	Super Lime Yellow	2.4	1000mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	570	Super Lime Green	2.0	1000mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	565	High Efficiency Green	2.1	200mcd @20mA	15°	GaP/GaP - Gallium Phosphide/Gallium Phosphide
	560	Super Pure Green	2.1	350mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
	555	Pure Green	2.1	80mcd @20mA	15°	GaP/GaP - Gallium Phosphide/ Gallium Phosphide
	525	Aqua Green	3.5	10,000mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride
	505	Blue Green	3.5	2000mcd @20mA	45°	SiC/GaN - Silicon Carbide / Gallium Nitride
	470	Super Blue	3.6	3000mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride
	430	Ultra Blue	3.8	100mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride



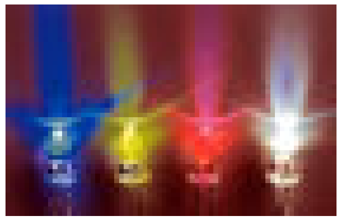
Tables, Graphs and Images are through the courtesy of LEDtronics 07/10/00

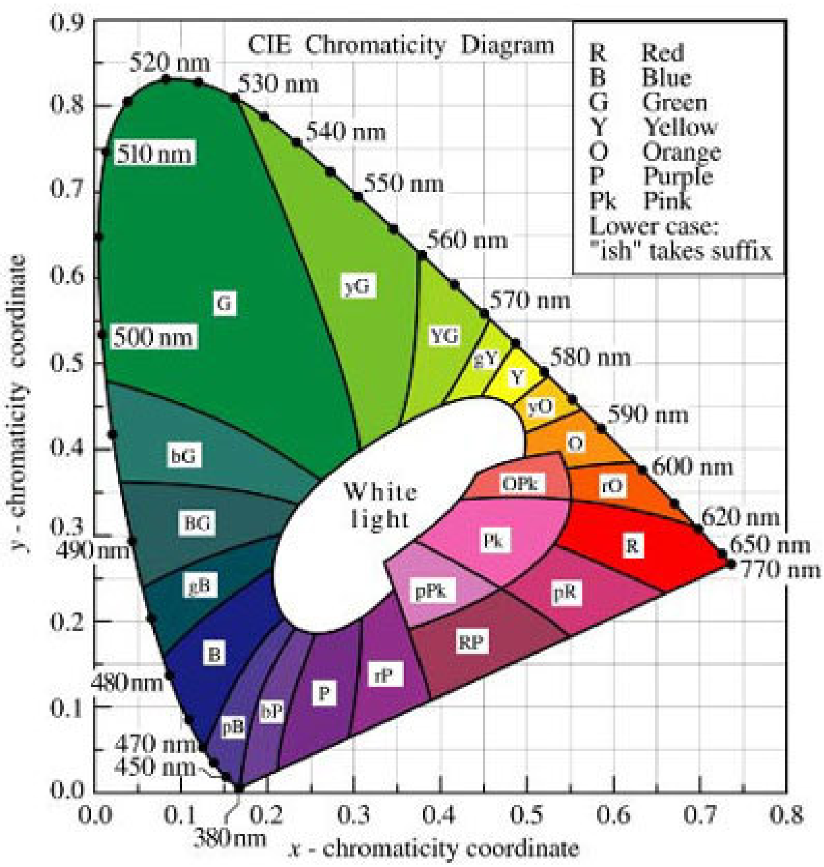
Disclaimer: The information provide herein are basics to educate one on the operating properties and user characteristics of LEDs. We do not imply that the information is accurate or applicable to every aspect of LED usage. Each application will have to be performed on its own merits and with full understanding that damages and injury are the sole responsibility of the "builder". We do not dispense engineering advice. You need to determine the specific products you will need for your specific application.

The LED color chart does NOT represent what OkSolar provide. This chart is only to be used as reference for the various types of LED's being manufactured today, and to show what their basic properties are.

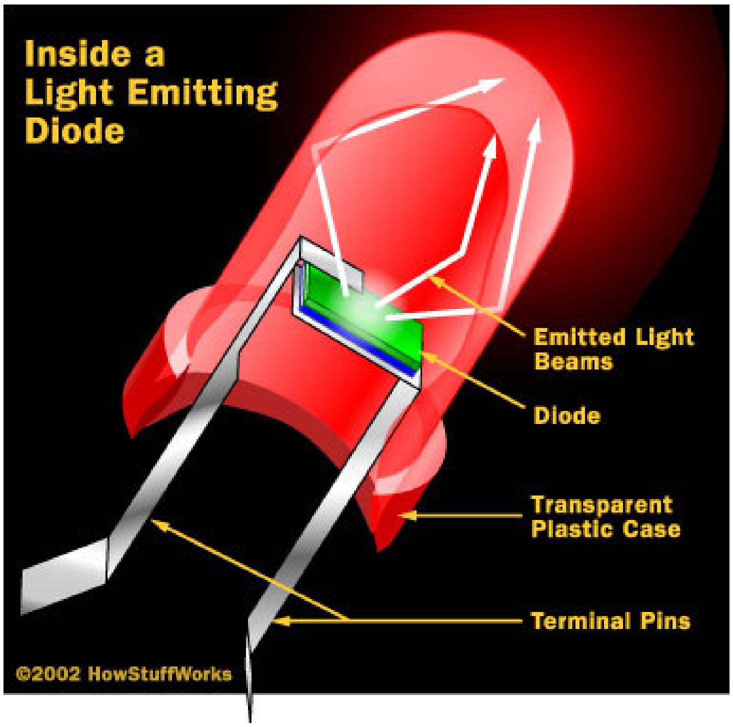
Led's Chromatic Chart

CIE Chromaticity diagram. Mono Chromatic colors are located on the perimeter and white colors are located in the center of the diagram

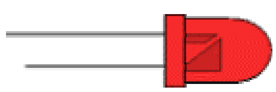
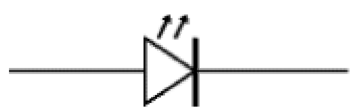




Light Emitting Diodes (LEDs)



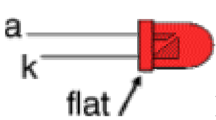
Basic components of a light emitting diode (LED).

Example:  Circuit symbol: 

Function

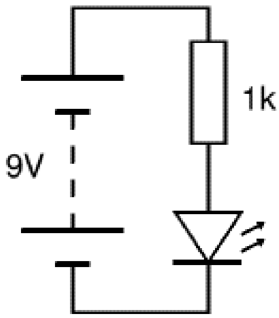
LEDs emit light when an electric current passes through them.

Connecting and soldering



LEDs must be connected the correct way round, the diagram may be labelled **a** or **+** for anode and **k** or **-** for cathode (yes, it really is k, not c, for cathode!). The cathode is the short lead and there may be a slight flat on the body of round LEDs. If you can see inside the LED the cathode is the larger electrode (but this is not an official identification method).

LEDs can be damaged by heat when soldering, but the risk is small unless you are very slow. No special precautions are needed for soldering most LEDs.



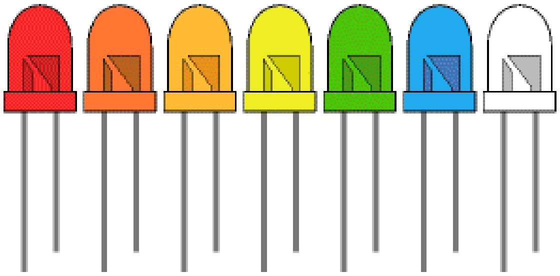
Testing an LED

Never connect an LED directly to a battery or power supply!
It will be destroyed almost instantly because too much current will pass through and burn it out.

LEDs must have a resistor in series to limit the current to a safe value, for quick testing purposes a 1kΩ resistor is suitable for most LEDs if your supply voltage is 12V or less. **Remember to connect the LED the correct way round!**

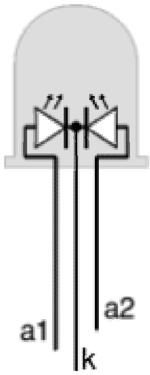
Colours of LEDs

LEDs are available in red, orange, amber, yellow, green, blue and white. Blue and white LEDs are much more expensive than the other colours.



The colour of an LED is determined by the semiconductor material, not by the colouring of the 'package' (the plastic body). LEDs of all colours are available in uncoloured packages which may be diffused (milky) or clear (often described as 'water clear'). The coloured packages are also available as diffused (the standard type) or transparent.

Tri-colour LEDs

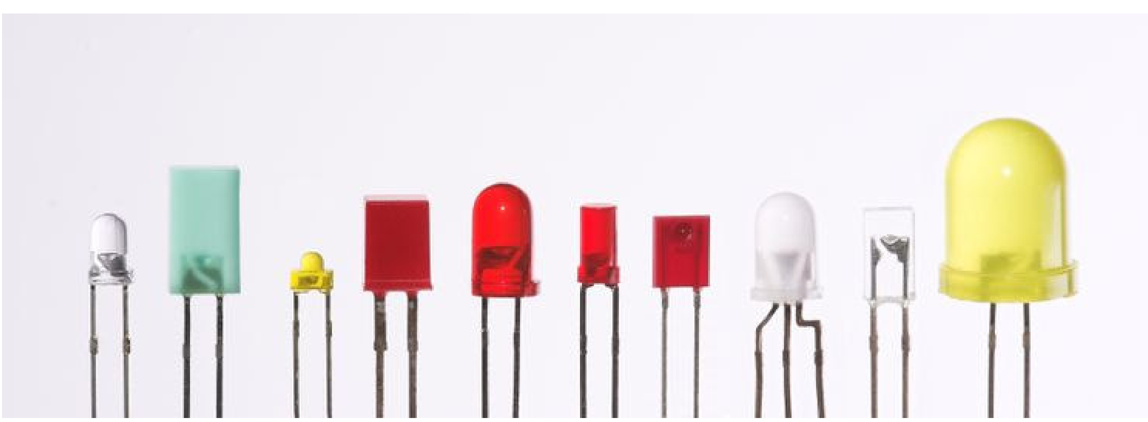


The most popular type of tri-colour LED has a red and a green LED combined in one package with three leads. They are called tri-colour because mixed red and green light appears to be yellow and this is produced when both the red and green LEDs are on.

The diagram shows the construction of a tri-colour LED. Note the different lengths of the three leads. The centre lead (k) is the common cathode for both LEDs, the outer leads (a1 and a2) are the anodes to the LEDs allowing each one to be lit separately, or both together to give the third colour.

Bi-colour LEDs

A bi-colour LED has two LEDs wired in 'inverse parallel' (one forwards, one backwards) combined in one package with two leads. Only one of the LEDs can be lit at one time and they are less useful than the tri-colour LEDs described above.



The table below shows typical technical data for some 5mm diameter round LEDs with diffused packages (plastic bodies). Only three columns are important and these are shown in bold. Please see below for explanations of the quantities.

Type	Colour	I_F max.	V_F typ.	V_F max.	V_R max.	Luminous intensity	Viewing angle	Wavelength
Standard	**Red**	**30mA**	**1.7V**	2.1V	5V	5mcd @ 10mA	60°	660nm
Standard	**Bright red**	**30mA**	**2.0V**	2.5V	5V	80mcd @ 10mA	60°	625nm
Standard	**Yellow**	**30mA**	**2.1V**	2.5V	5V	32mcd @ 10mA	60°	590nm
Standard	**Green**	**25mA**	**2.2V**	2.5V	5V	32mcd @ 10mA	60°	565nm
High intensity	**Blue**	**30mA**	**4.5V**	5.5V	5V	60mcd @ 20mA	50°	430nm
Super bright	**Red**	**30mA**	**1.85V**	2.5V	5V	500mcd @ 20mA	60°	660nm
Low current	**Red**	**30mA**	**1.7V**	2.0V	5V	5mcd @ 2mA	60°	625nm

I_F max.	Maximum forward current, forward just means with the LED connected correctly.
V_F typ.	Typical forward voltage, V_L in the LED resistor calculation. This is about 2V, except for blue and white LEDs for which it is about 4V.
V_F max.	Maximum forward voltage.
V_R max.	Maximum reverse voltage You can ignore this for LEDs connected the correct way round.
Luminous intensity	Brightness of the LED at the given current, mcd = millicandela.
Viewing angle	Standard LEDs have a viewing angle of 60°, others emit a narrower beam of about 30°.
Wavelength	The peak wavelength of the light emitted, this determines the colour of the LED. nm = nanometre.

Sizes, Shapes and Viewing angles of LEDs

LEDs are available in a wide variety of sizes and shapes. The 'standard' LED has a round cross-section of 5mm diameter and this is probably the best type for general use, but 3mm round LEDs are also popular.

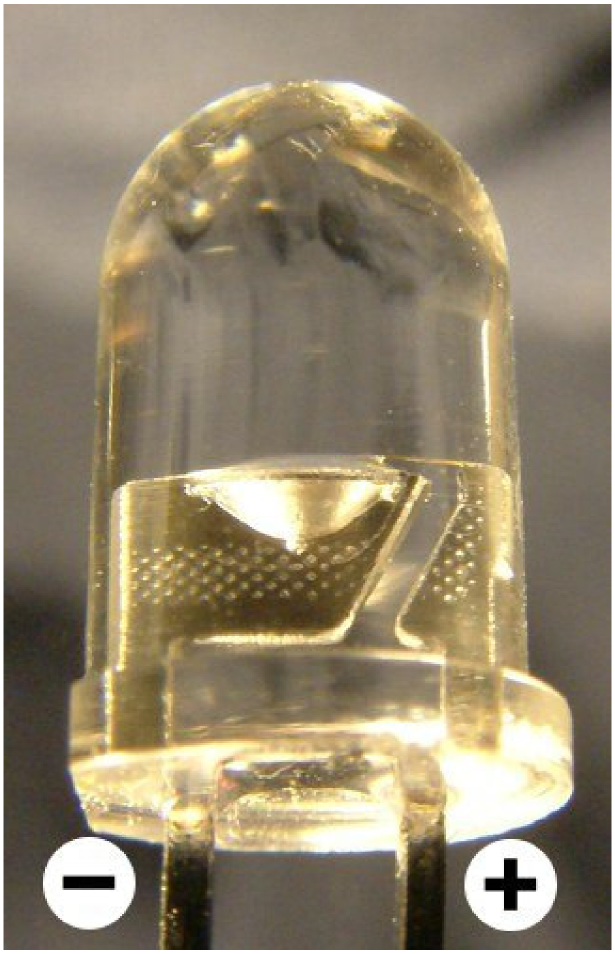
LED Clip

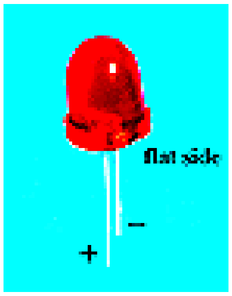
Round cross-section LEDs are frequently used and they are very easy to install on boxes by drilling a hole of the LED diameter, adding a spot of glue will help to hold the LED if necessary. LED clips are also available to secure LEDs in holes. Other cross-section shapes include square, rectangular and triangular.

As well as a variety of colours, sizes and shapes, LEDs also vary in their viewing angle. This tells you how much the beam of light spreads out. Standard LEDs have a viewing angle of 60° but others have a narrow beam of 30° or less.

What is Inside an LED?

LED's are special diodes that emit light when connected in a circuit. They are frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not. A clear (or often colored) epoxy case enclosed the heart of an LED, the semi-conductor chip.





LED leads

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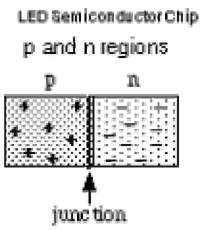
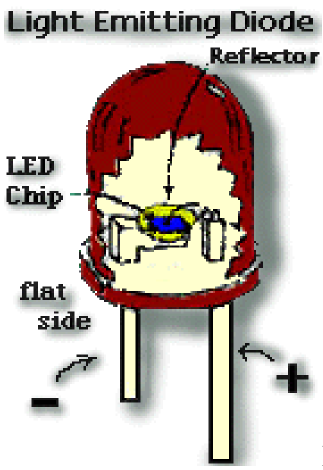
side lead on flat side of bulb = negative

The two wires extending below the LED epoxy enclosure, or the "bulb" indicate how the LED should be connected into a circuit. The *negative* side of an LED lead is indicated in two ways: 1) by the *flat side* of the bulb, and 2) by the *shorter* of the two wires extending from the LED. The negative lead should be connected to the negative terminal of a battery. LED's operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 *milli*amperes. Voltages and currents substantially above these values can melt a LED chip.



The most important part of a *light emitting diode (LED)* is the semi-conductor chip located in the center of the bulb as shown at the right. The chip has two regions separated by a *junction*. The *p region* is dominated by positive electric charges, and the *n region* is dominated by negative electric charges. The *junction* acts as a barrier to the flow of electrons between the *p* and the *n regions*. Only when sufficient voltage is applied to the semi-conductor chip, can the current flow, and the electrons cross the junction into the *p region*.



In the absence of a large enough electric potential difference (voltage) across the LED leads, the *junction* presents an electric potential barrier to the flow of electrons.

What Causes the LED to Emit Light and What Determines the Color of the Light?

When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the *junction* between the *p* and *n* regions. In the *p region* there are many more positive than negative charges. In the *n region* the electrons are more numerous than the positive electric charges. When a voltage is applied and the current starts to flow, electrons in the *n region* have sufficient energy to move across the junction into the *p region*. Once in the *p region* the electrons are immediately attracted to the positive charges due to the mutual Coulomb forces of attraction between opposite electric charges. When an electron moves sufficiently close to a positive charge in the *p region*, the two charges "re-combine".

Each time an electron *recombines* with a positive charge, electric potential energy is converted into electromagnetic energy. For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material (usually a combination of the chemical elements gallium, arsenic and phosphorus). Only photons in a very narrow frequency range can be emitted by any material. LED's that emit different colors are made of different semi-conductor materials, and require different energies to light them.

How Much Energy Does an LED Emit?

The electric energy is proportional to the voltage needed to cause electrons to flow across the p-n junction. The different colored LED's emit predominantly light of a single color. The energy (E) of the light emitted by an LED is related to the electric charge (q) of an electron and the voltage (V) required to light the LED by the expression: $E = qV$ Joules. This expression simply says that the voltage is proportional to the electric energy, and is a general statement which applies to any circuit, as well as to LED's. The constant q is the electric charge of a single electron, -1.6×10^{-19} *Coulomb*.

Finding the Energy from the Voltage

Suppose you measured the voltage across the leads of an LED, and you wished to find the corresponding energy required to light the LED. Let us say that you have a red LED, and the voltage measured between the leads of is 1.71 Volts. So the Energy required to light the LED is $E = qV$ or $E = -1.6 \times 10^{-19}$ (1.71) Joule, since a Coulomb-Volt is a Joule. Multiplication of these numbers then gives $E = 2.74 \times 10^{-19}$ Joule.

Finding the Frequency from the Wavelength of Light

The frequency of light is related to the wavelength of light in a very simple way. The spectrometer can be used to examine the light from the LED, and to estimate the peak wavelength of the light emitted by the LED. But we prefer to have the frequency of the peak intensity of the light emitted by the LED. The wavelength is related to the frequency of light by $f = \frac{c}{\lambda}$, where c is the speed of light (3×10^8 m/s) and λ is the wavelength of light read from the spectrometer (in units of nanometers or 10^{-9} meters). Suppose you observed the red LED through the spectrometer, and found that the LED emits a range in colors with maximum intensity corresponding to a wavelength as read from the spectrometer of $\lambda = 660$ nm or 660×10^{-9} m. The corresponding frequency at which the red LED emits most of its light is $f = \frac{3 \times 10^8}{660 \times 10^{-9}} \frac{ms^{-1}}{m}$ or 4.55×10^{14} *Hertz*. The unit for one cycle of a wave each second (cycle per second) is a Hertz.