Lec. 1
Basic Electrical / Electronic Circuit Components

1

Circuit Components

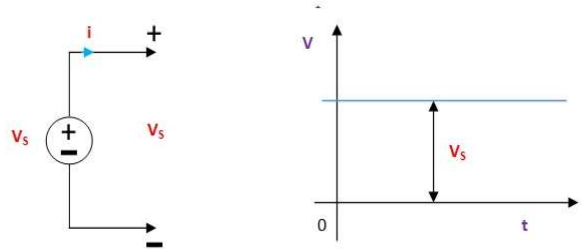
Passive Components: Resistors, Capacitors, Inductors, transformer etc.

Active Components: Power sources (voltage/current),
Transistors (BJT/ MOSFET),
Diodes (LEDs, Photodiodes),
Generators etc

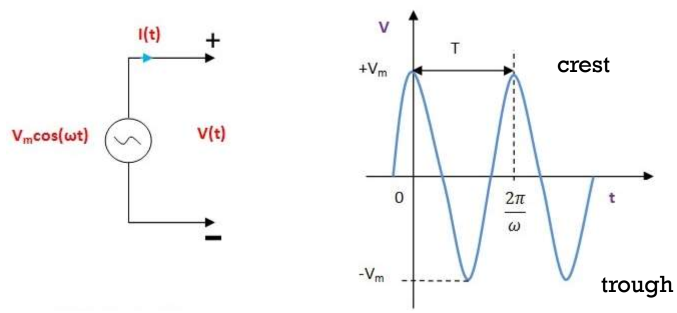
2

(Ideal Voltage Sources)

DC Voltage Source



Alternating Voltage Source



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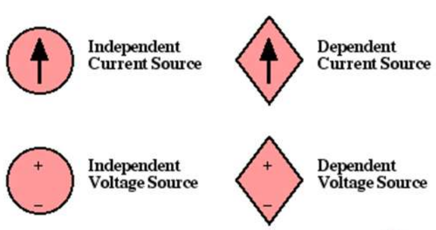
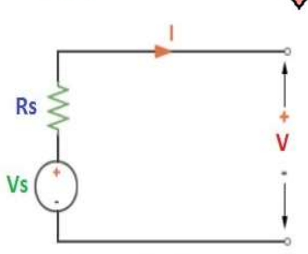
Sources Types (DC/AC)

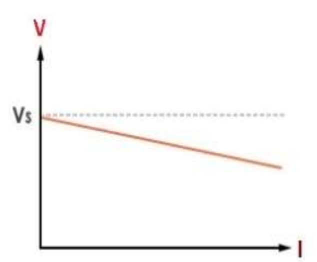
A. Independent
1. Voltage
2. Current

B. Dependent
1. Voltage dependent Voltage Source, $v(v_x)$
2. Current dependent Voltage Source, $v(i_x)$
3. Voltage dependent Current Source, $i(v_x)$
4. Current dependent Current Source, $i(i_x)$

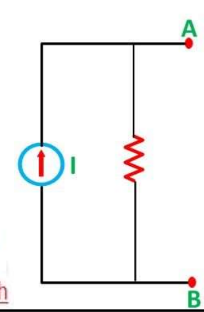


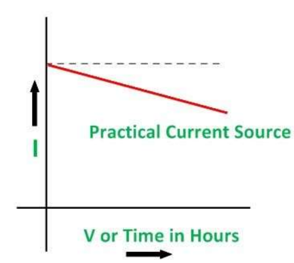


Practical Voltage Source



Practical Voltage Source Graph





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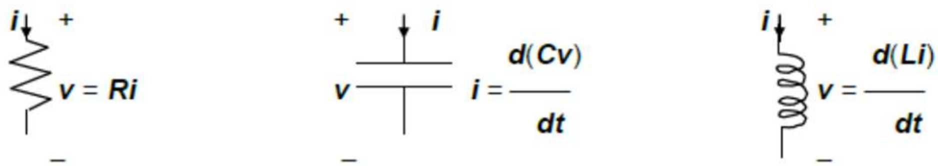
Linear Time Invariant Passive Elements



Linear Resistor   Linear Capacitor   Linear Inductor

For linear time-invariant capacitors and inductors, $i = C(dv/dt)$ and $v = L(di/dt)$ respectively.

Steady State and Transient Behaviour

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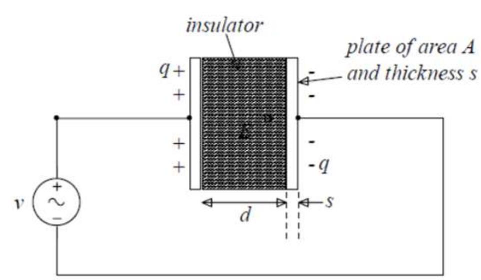
Capacitor



A capacitor stores energy in the form of an electric field

Current-voltage relationship $\boxed{i = C\frac{dv}{dt}, \quad v = \frac{1}{C}\int i dt}$

In DC the capacitor acts as an open circuit

The capacitance C represents the efficiency of storing charge.

The unit of capacitance is the Farad (F). 1 Farad=1Coulomb/1Vol

Typical capacitor values are in the mF (10^{-3} F) to pF (10^{-12} F)

The energy stored in a capacitor is $E = \frac{1}{2}Cv^2$ Joules

Large capacitors should always be stored with shorted leads.

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$$\boxed{i = C\frac{dv}{dt}} \qquad \textbf{(1)}$$

Integrating Eq.1

$$\int_{-\infty}^{t} i\,dt = \int_{-\infty}^{t} C\frac{dv}{dt}dt$$

$$v = \frac{1}{C}\int_{-\infty}^{t} i\,dt$$

$$= \frac{1}{C}\int_{0}^{t} i\,dt + v(0)$$

v(0)= q(0)/C

The constant of integration *v(0)* represents the voltage of the capacitor at time *t=0*.
The presence of the constant of integration *v(0)* is the reason for the memory properties of the capacitor.

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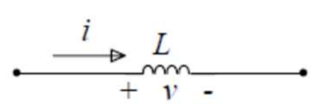
Inductor



A inductor stores energy in a magnetic field

Current-voltage relationship $\boxed{v = L\frac{di}{dt}, \quad i = \frac{1}{L}\int v dt}$

The energy stored in an inductor is $E = \frac{1}{2}Li^2$ Joules

In DC the inductor behaves like a short circuit

The inductance L represents the efficiency of storing magnetic flux.

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$$\boxed{v = L\frac{di}{dt}} \qquad \textbf{(2)}$$

On integrating Eq. 2

$$\int_{-\infty}^{t} v dt = \int_{-\infty}^{t} L\frac{di}{dt}dt$$

$$i = \frac{1}{L}\int_{-\infty}^{t} v\,dt$$

$$= \frac{1}{L}\int_{0}^{t} v\,dt + i(0)$$

The constant *i(0)* represents the current through the inductor at time *t=0*. (Note that we have also assumed that the current at $t = -\infty$ was zero.)

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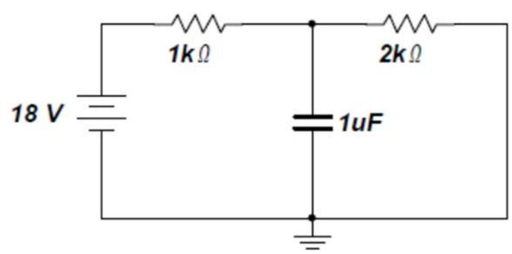
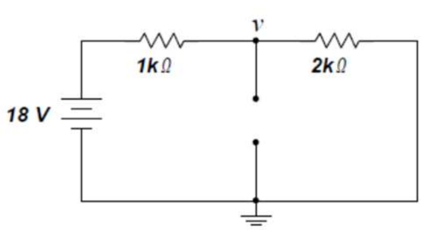
Q. 1.

Calculate the energy stored in the capacitor of the circuit to the right under DC conditions.





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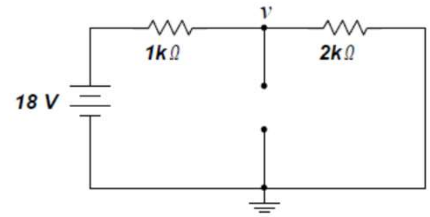

And from the voltage divider formed by the 1kΩ and the 2kΩ resistors the voltage v is 12Volts. Therefore the energy stored in the capacitor is

$$Ec = \frac{1}{2}Cv^2 = \frac{1}{2}1\times10^{-6}\times12^2 = 72\,\mu\text{Joules}$$

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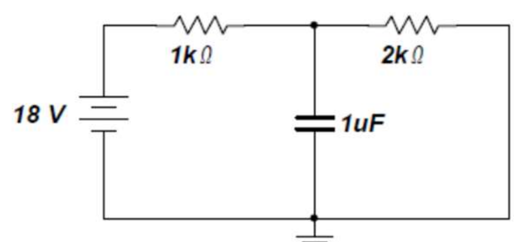
H.W.

If the capacitor is replaced by an inductor (1mH) then how much energy is stored by it.



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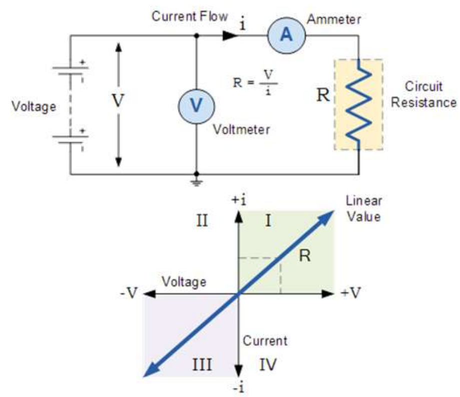
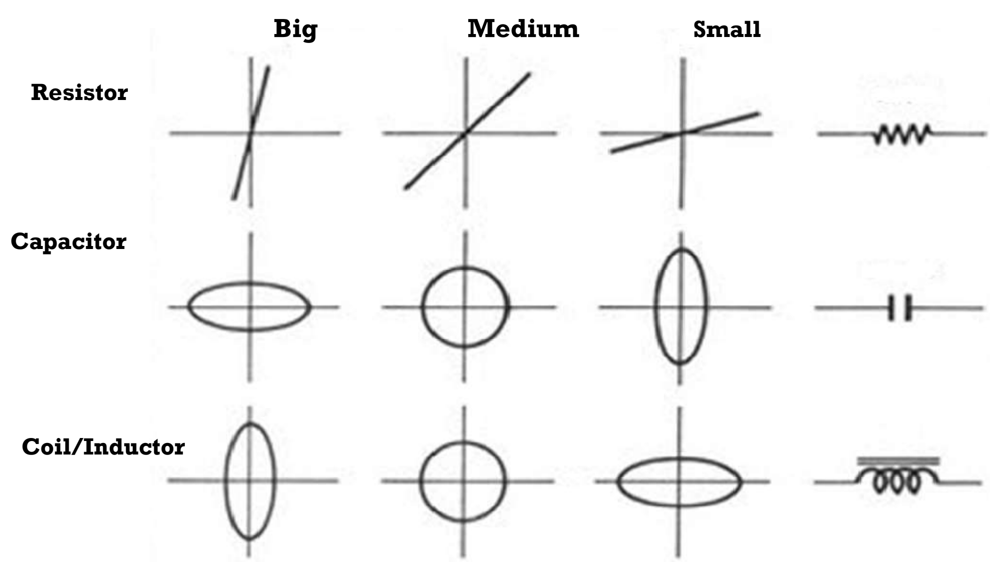
Steady State I-V Characteristics of R

With DC Sources



Steady State I-V Characteristics of R, C and L

With AC Source

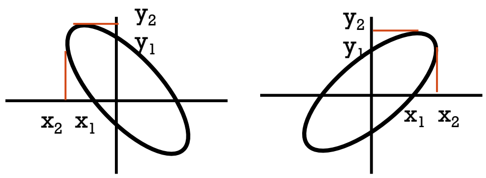


Basic Lissajous Curves

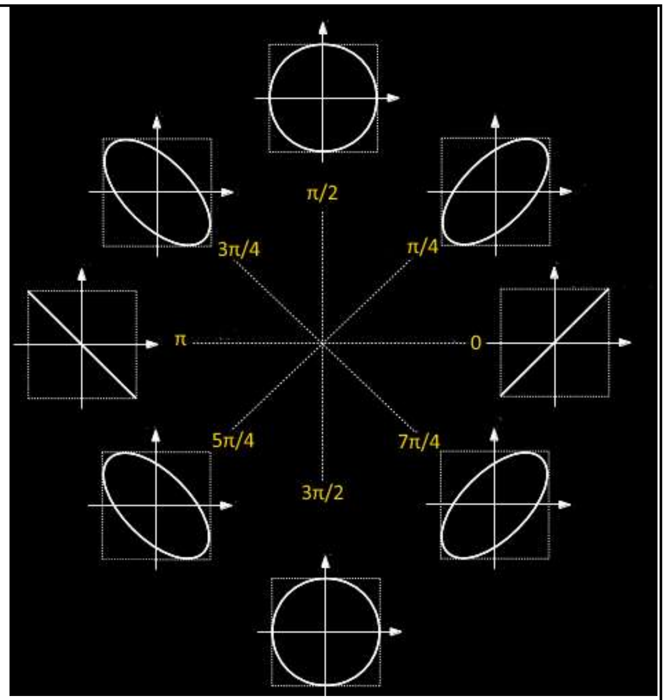
Lissajous figures are created by the combination of two sine waves

$V_h = A \sin(\omega t)$

$V_v = B \sin(\omega t + \emptyset)$



$\emptyset = 180 - sin^{-1}(x_1/x_2)$	$\emptyset = sin^{-1}(x_1/x_2)$
$\emptyset = 180 + sin^{-1}(x_1/x_2)$	$\emptyset = 360 - sin^{-1}(x_1/x_2)$



https://datagenetics.com/blog/april22015/index.html

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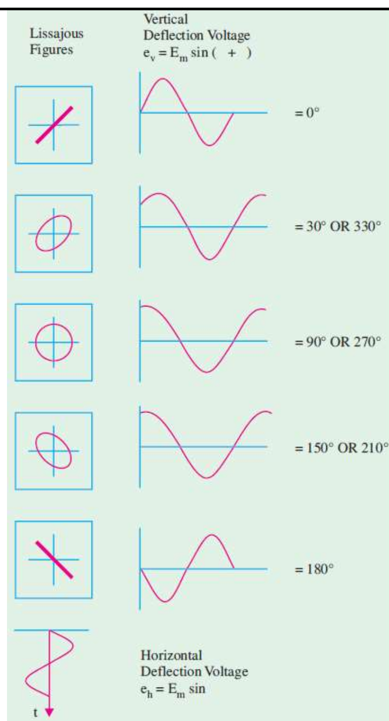

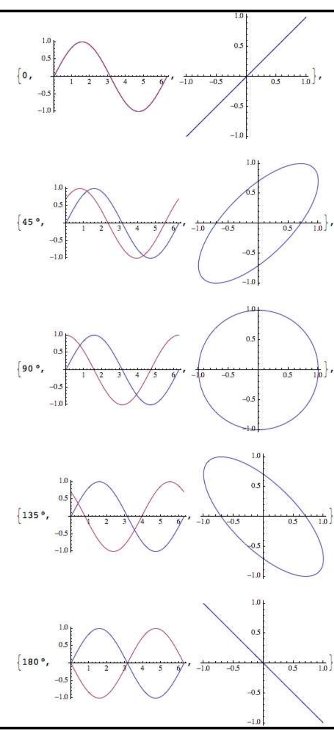

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Materials

Classification:- In terms of Electrical Conductivity
- Conductor
- Insulator
- Semiconductor

Si-crystal (semiconductor)
Intrinsic (pure):
Extrinsic (doped):
- p-type (trivalent doping ions e.g. B) and
- n-Type (pentavalent doping ions e.g. P)

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Electron concentration gradient

- $n = n_{n0}$ (*n*-side) > $n = np_0$ (*p*-side)

⇨Electrons *diffuse* towards the left and enter the *p*-region and recombine with the holes (majority carriers)

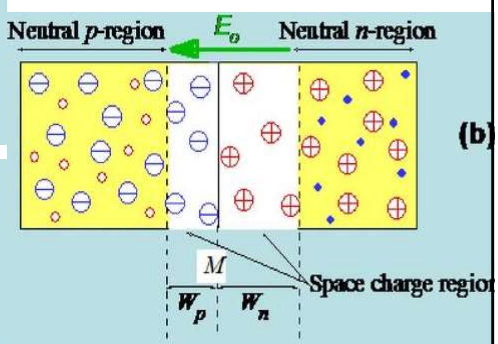
⇨The *p*-side near the junction becomes depleted of majority carriers and has exposed negative acceptors of concentration N_a.

Hole concentration gradient

- $p = p_{p0}$ (*p*-side) > $p = p_{n0}$ (*n*-side)

⇨Holes *diffuse* towards the right and enter the *n*-region and recombine with the electrons (majority carriers) in this region.

⇨The *n*-side near the junction becomes depleted of majority carriers and has exposed positive donors of concentration N_d.



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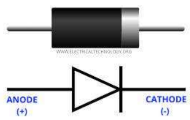
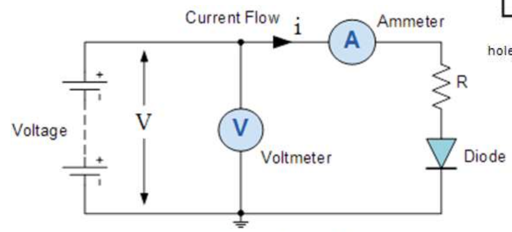
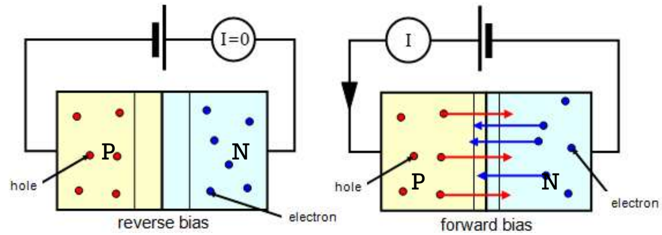
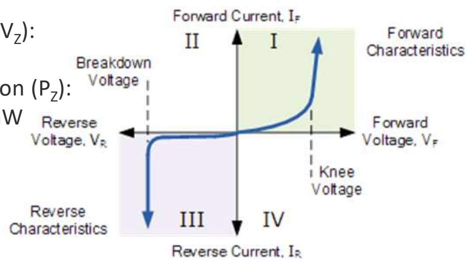
P-N Junction Diode

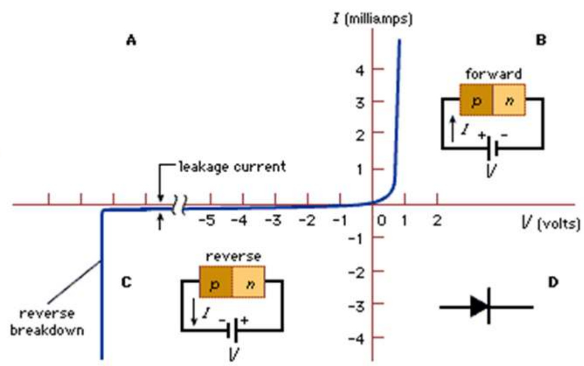






E.g.
- Zener Voltage (V_Z): 3.3V
- Power dissipation (P_Z): 500mW
- Zener current (I_{ZT}): 76mA





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P-N Junction Diode

General Purpose Diode:

Zener Diode,

LED(**Light Emitting Diode**),

Generic Diode

Zener Diode

LED

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Light Emitting Diodes

- A **l**ight **e**mitting **d**iode (LED) is a *pn* junction diode typically made from a direct bandgap semiconductor in which the electron hole pair recombination results in the emission of a photon.
- Emitted photon energy

$$h\nu \approx E_g$$

Bandgap energy

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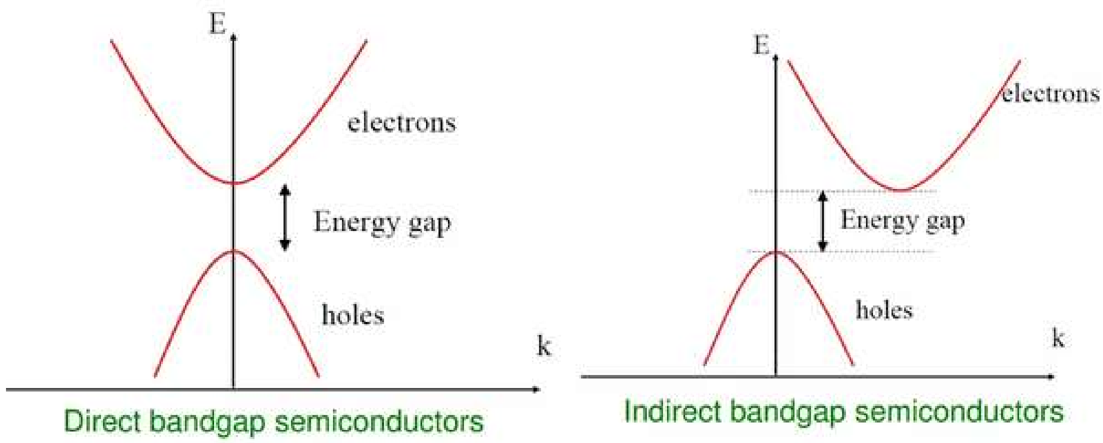
Types of Energy Bandgap in Semiconductors

E-K diagram (Energy -Mometum)



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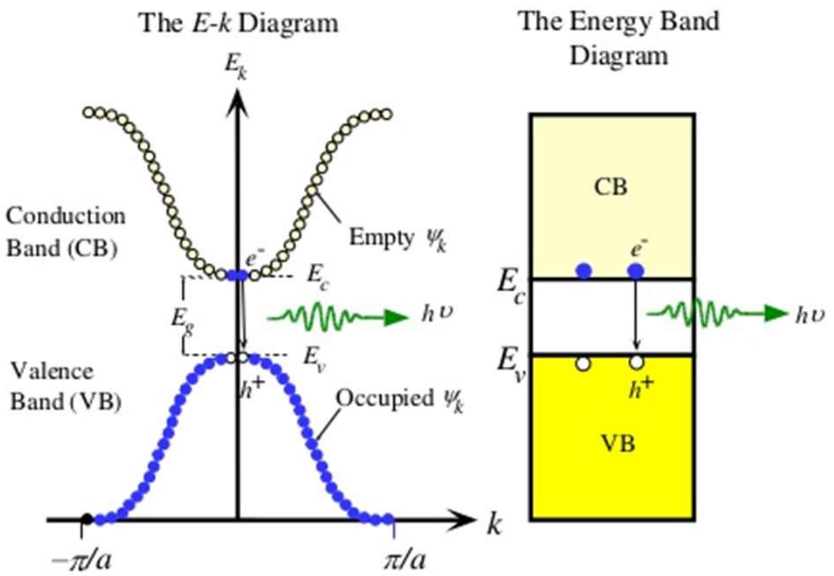
Direct- Bandgap Semiconductors are suitable for visible light Emission



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Light Wavelength and Equivalent Semiconductor Bandgap

Colour	Wavelength (nm)	Band Gap Energy, E (eV)
Infrared	$\lambda>760$	$E<1.63$
Red	$610<\lambda<760$	$1.63<E<2.03$
Orange	$590<\lambda<610$	$2.03<E<2.10$
Yellow	$570<\lambda<590$	$2.10<E<2.18$
Green	$500<\lambda<570$	$2.18<E<2.48$
Blue	$450<\lambda<500$	$2.48<E<2.76$
Violet	$400<\lambda<450$	$2.76<E<3.10$
Ultraviolet	$\lambda<400$	$3.1<E$

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Photon energy, wavelength and color

Wavelength ranges and colors as usually specified for LEDs

Color	Blue	Emerald Green	Green	Yellow	Amber	Orange	Red-Orange	Red	Deep red	Infrared
λ (nm)	$\lambda < 500$	530–564	565–579	580–587	588–594	595–606	607–615	616–632	632–700	$\lambda > 700$

$$E = h\nu = \frac{hc}{\lambda} = \frac{(4.14\times10^{-15}\ \text{eV}\cdot\text{s})\times(2.9979\times10^{17}\ \text{nm/s})}{\lambda}$$

$$= \frac{1240\ \text{eV}\cdot\text{nm}}{\lambda}$$

$$\Rightarrow \boxed{\lambda(\text{nm}) = \frac{1240\ \text{eV}\cdot\text{nm}}{E(\text{eV})}}$$

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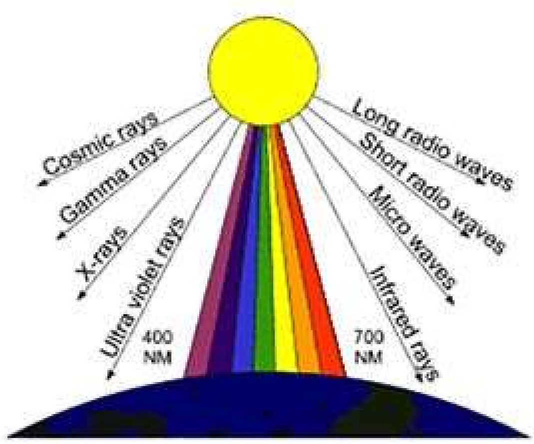

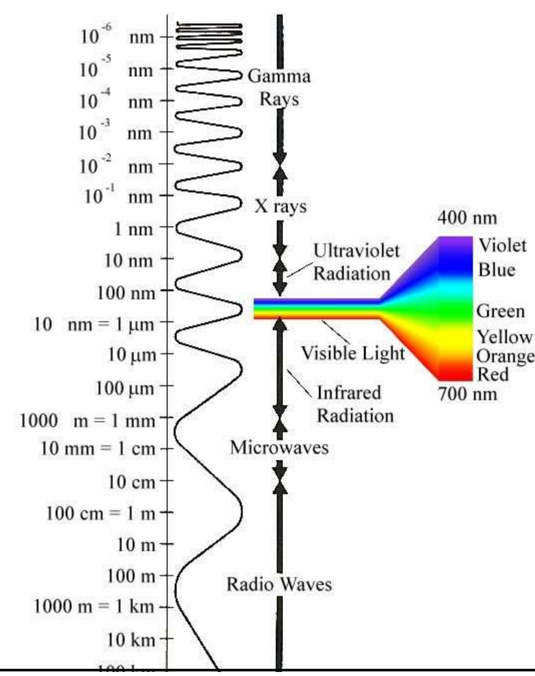

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Different LED's Colour

Typical LED Characteristics			
Semiconductor Material	Wavelength	Colour	V_F @ 20mA
GaAs	850-940nm	Infra-Red	1.2v
GaAsP	630-660nm	Red	1.8v
GaAsP	605-620nm	Amber	2.0v
GaAsP:N	585-595nm	Yellow	2.2v
AlGaP	550-570nm	Green	3.5v
SiC	430-505nm	Blue	3.6v
GaInN	450nm	White	4.0v

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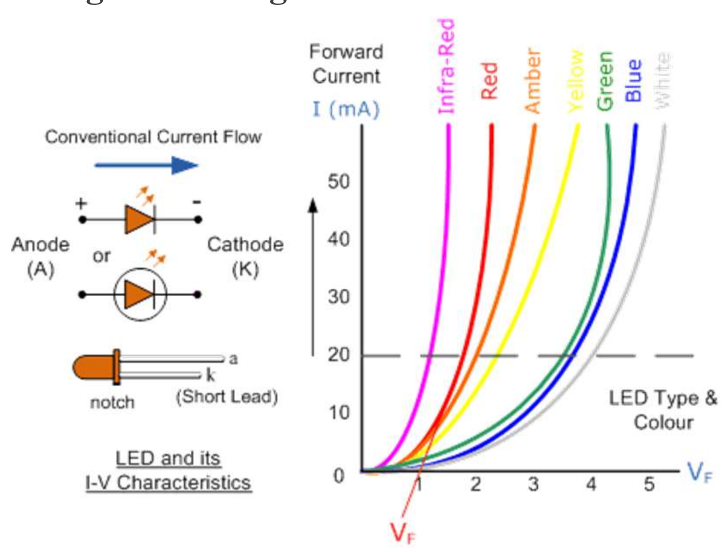
Light Emitting Diodes I-V Characteristics



Light Emitting Diode (LED) Schematic symbol and I-V Characteristics Curves showing the different colours available

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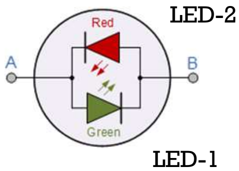
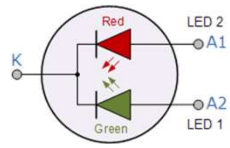
A Bi-colour LED



A Multi or Tricoloured LED



Colour	Green	Red	Yellow
LED Selected	Terminal A/DC		AC supply (low voltage, low frequency)
	+	−	
LED 1	ON	OFF	ON
LED 2	OFF	ON	ON

Output Colour	Red	Orange	Yellow	Green
LED 1 Current	0	5mA	9.5mA	15mA
LED 2 Current	10mA	6.5mA	3.5mA	0

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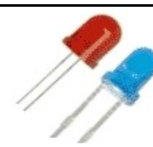
LED's Advantages



LED

Normal incandescent lamps and bulbs generate large amounts of heat when illuminated.

The light emitting diode produces a "cold" generation of light which leads to high efficiencies than the normal "light bulb" because most of the generated energy radiates away within the visible spectrum.

LEDs are solid-state devices:

- can be extremely small
- durable and
- provide much longer lamp life than normal light sources.

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Other application of PN junction Diode

Solar Cell

Photovoltaic

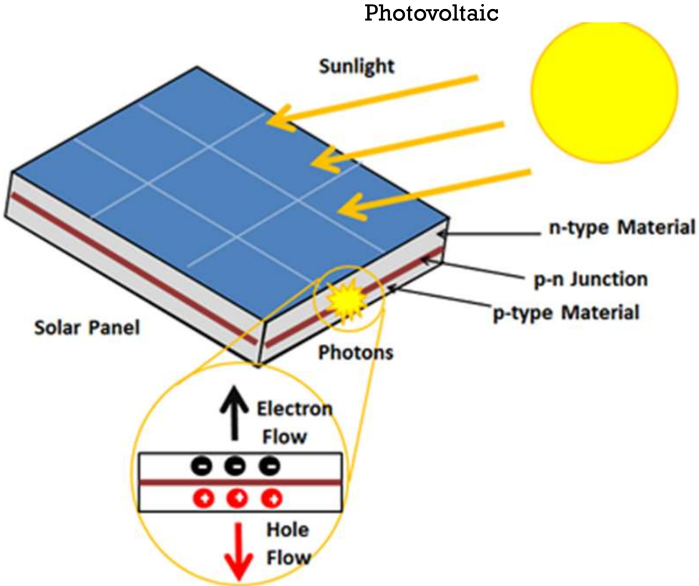
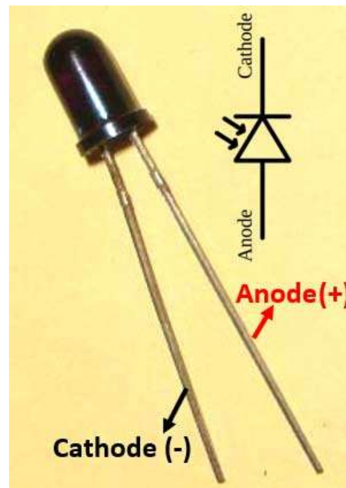


Photo-Diode

Photo-conduction



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