# 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)

# 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)

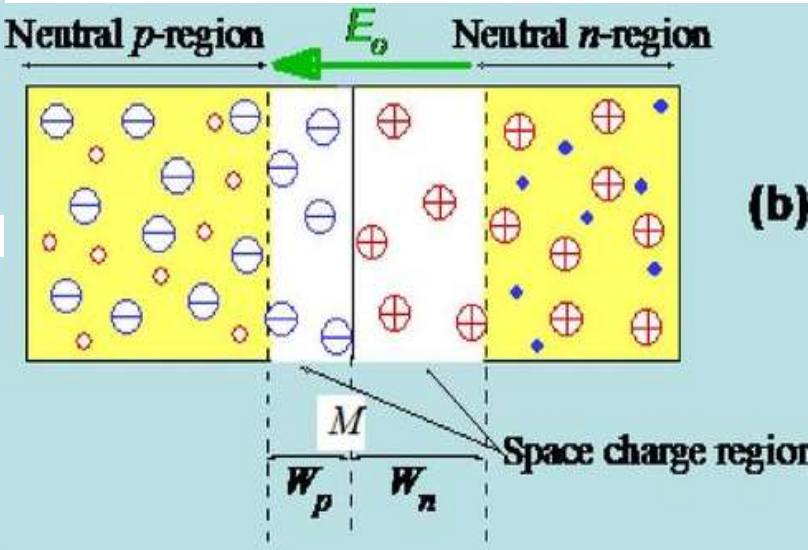
⇨The *p*-side near the junction becomes depleted of majority carriers and has exposed negative acceptors of concentration $N_a$.

# Hole concentration gradient

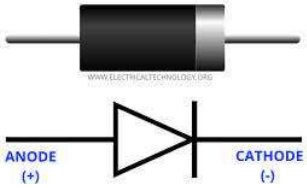
- $p = p_{p0}$ (*p*-side) > $p = p_{n0}$ (*n*-side)

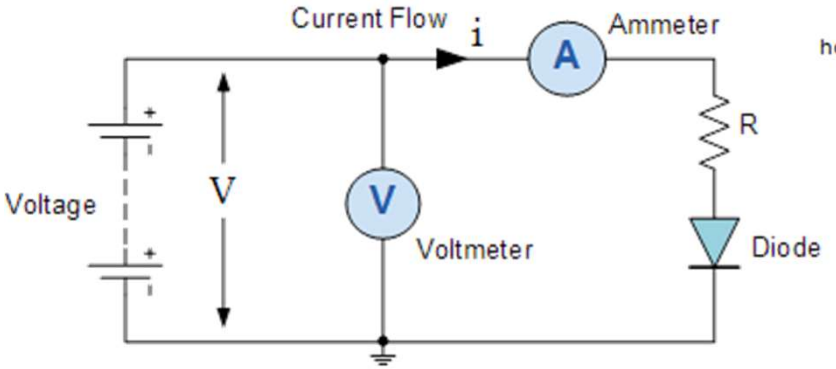
⇨Holes *diffuse* towards the right and enter the *n*-region and recombine with the electrons (majority carriers) in this region.

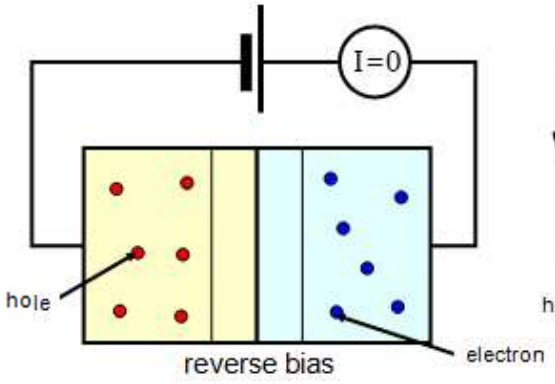
⇨The *n*-side near the junction becomes depleted of majority carriers and has exposed positive donors of concentration $N_d$.

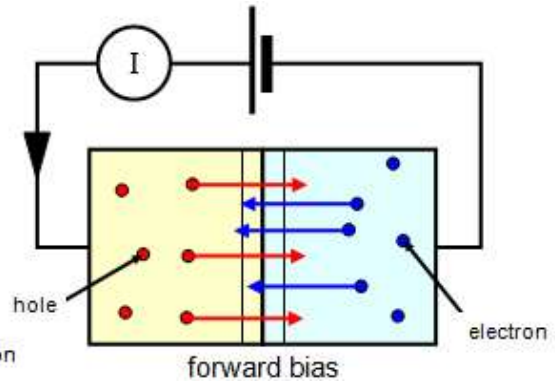


# P-N Junction Diode



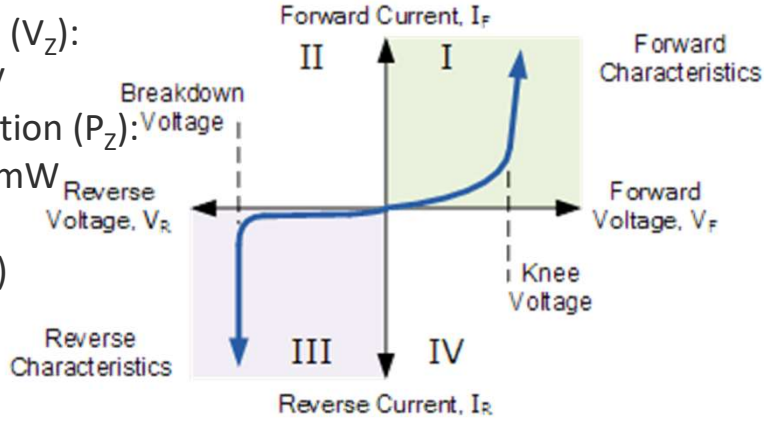



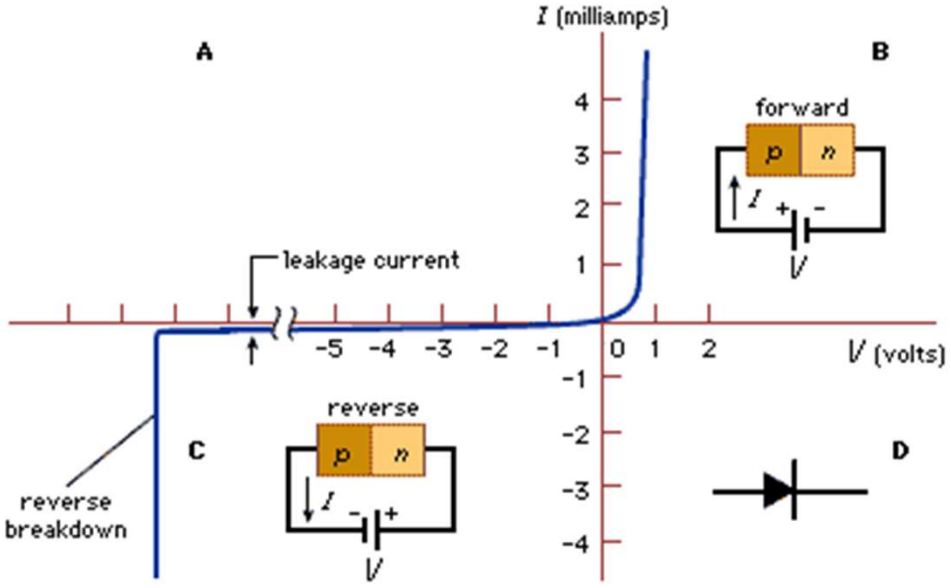




E.g.

- Zener Voltage ($V_Z$): 3.3V
- Power dissipation ($P_Z$): 500mW
- Zener current (Max. Allowed) $I_{zmax}$= 151 mA



# P-N Junction Diode

General Purpose Diode:

Zener Diode,

LED(**Light Emitting Diode**),

Generic Diode

Zener Diode

LED

# Light Emitting Diodes

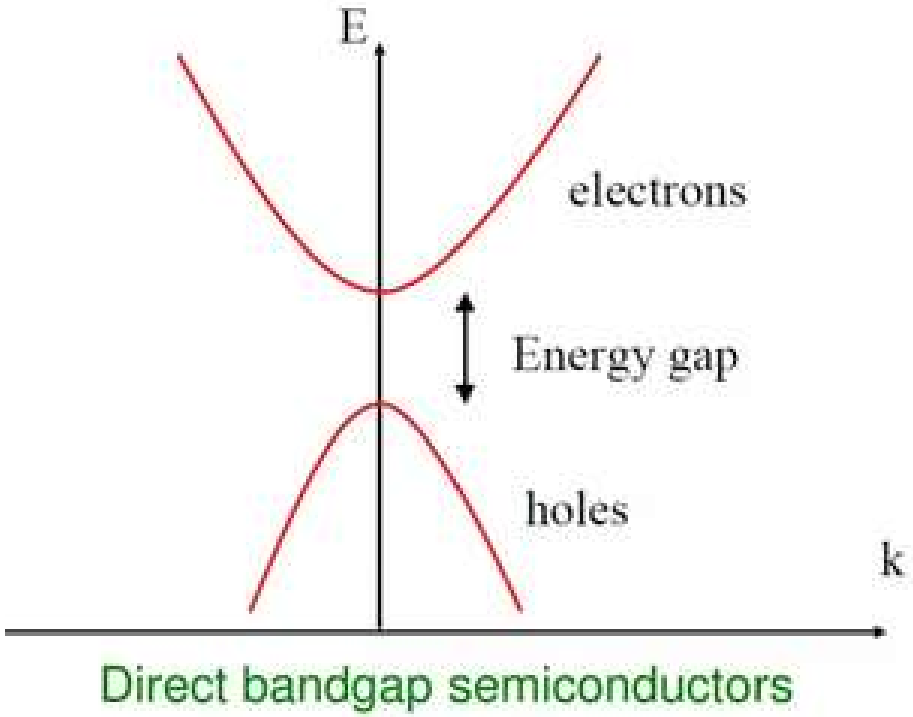
- A **l**ight **e**mitting **d**iode (LED) is a *pn* junction diode typically made from a direct bandgap semiconductor in which the electron hole pair recombination results in the emission of a photon.
- Emitted photon energy

$$h\nu \approx E_g$$

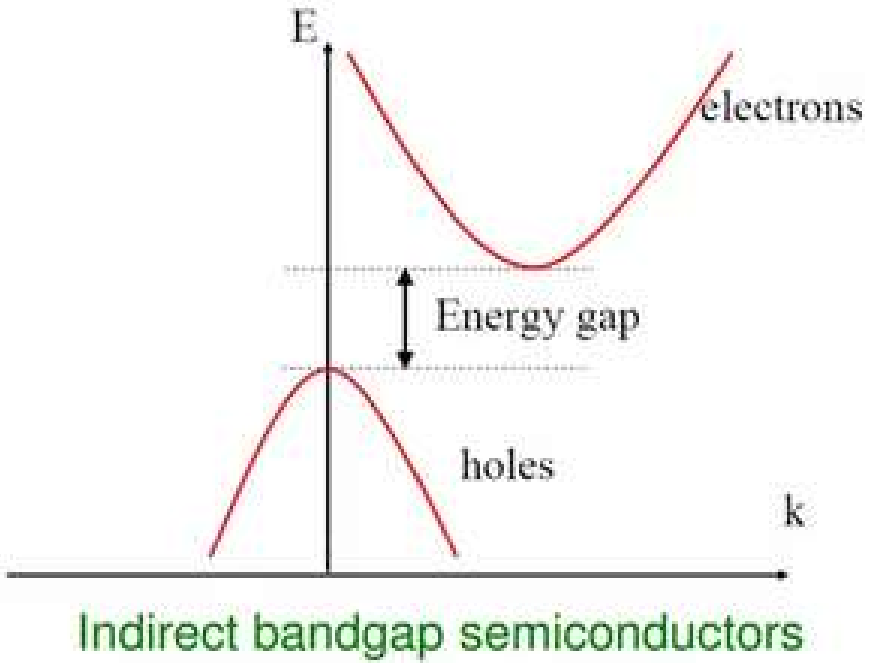
↑ Bandgap energy

# Types of Energy Bandgap in Semiconductors

E-K diagram (Energy -Mometum)

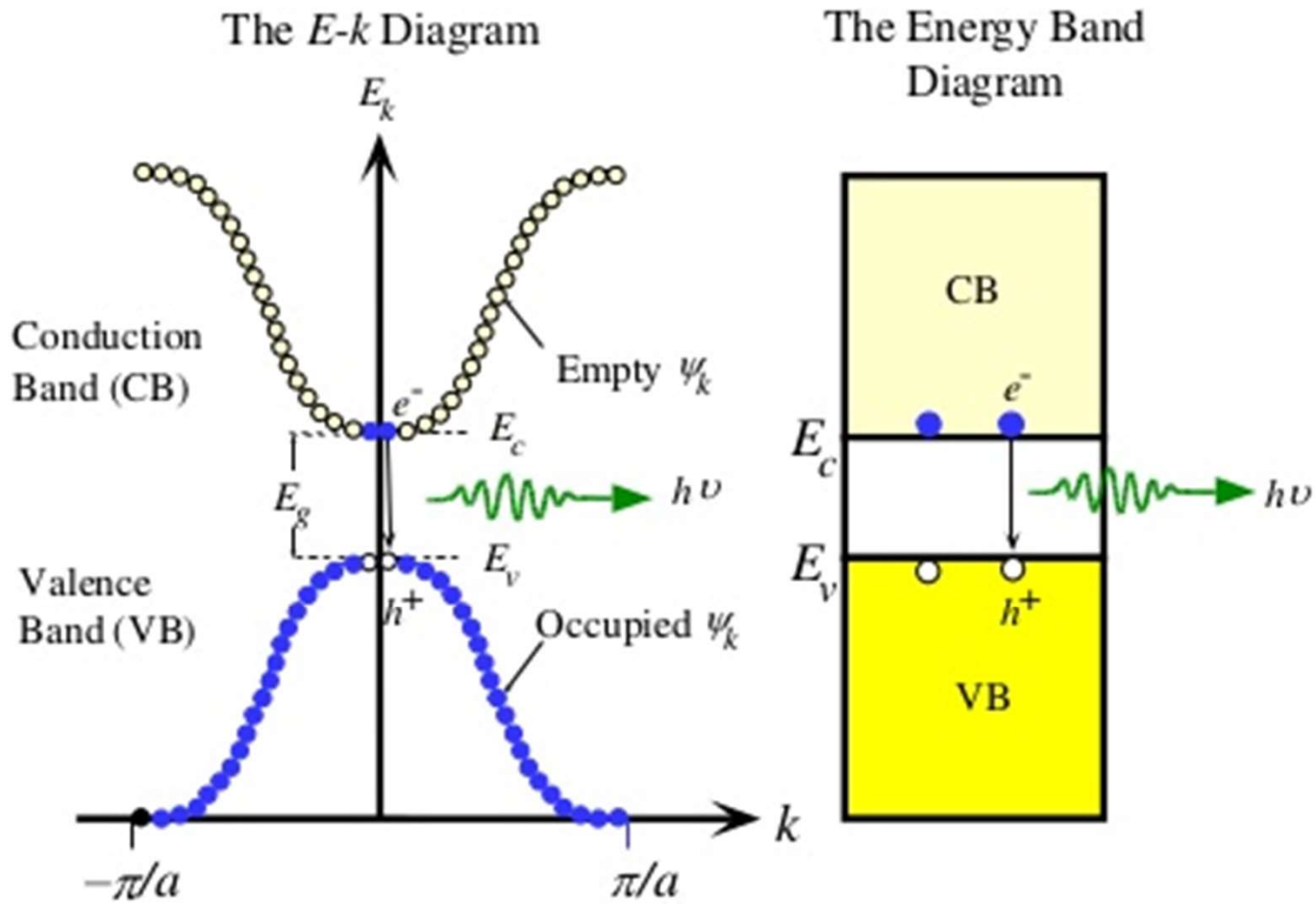



Direct bandgap semiconductors




Indirect bandgap semiconductors

# Direct- Bandgap Semiconductors are suitable for visible light Emission



# 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 | $\lambda < 400$ | $3.1 < E$ |

# Photon energy, wavelength and color

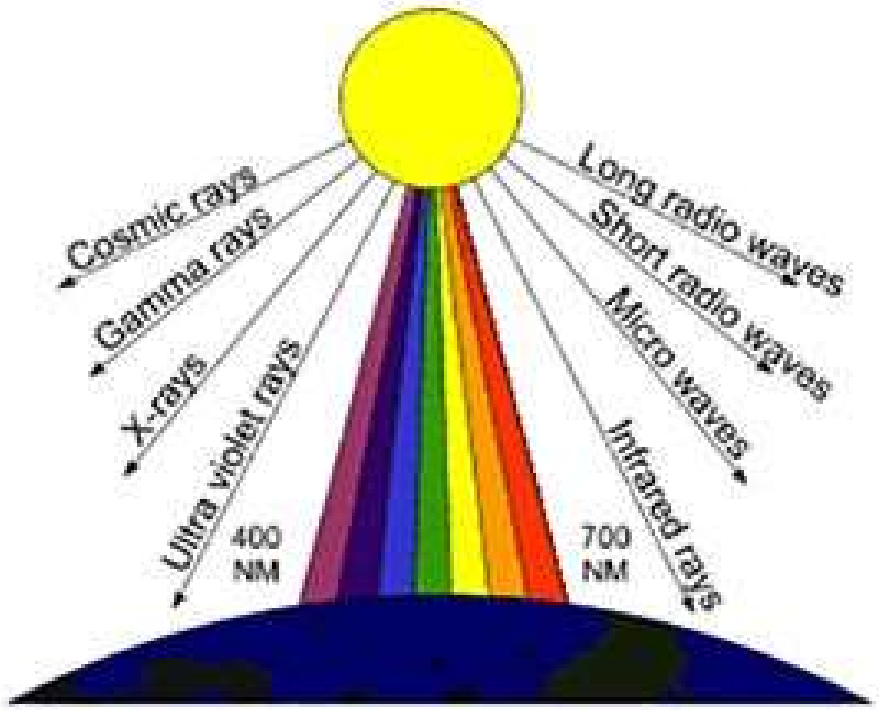
Wavelength ranges and colors as usually specified for LEDs

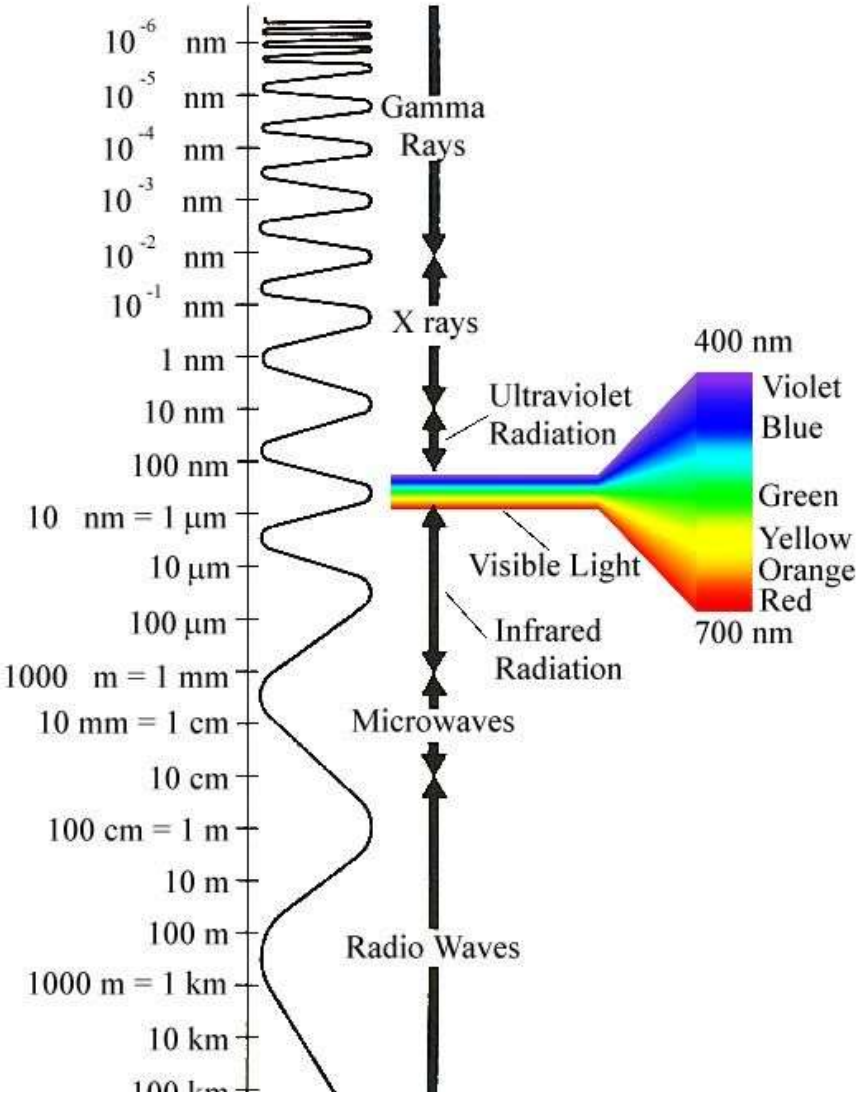
| Color | Blue | Emerald Green | Green | Yellow | Amber | Orange | Red-Orange | Red | Deep red | Infrared |
|---|---|---|---|---|---|---|---|---|---|---|
| λ (nm) | $\lambda < 500$ | 530–564 | 565–579 | 580–587 | 588–594 | 595–606 | 607–615 | 616–632 | 632–700 | $\lambda > 700$ |

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

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

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

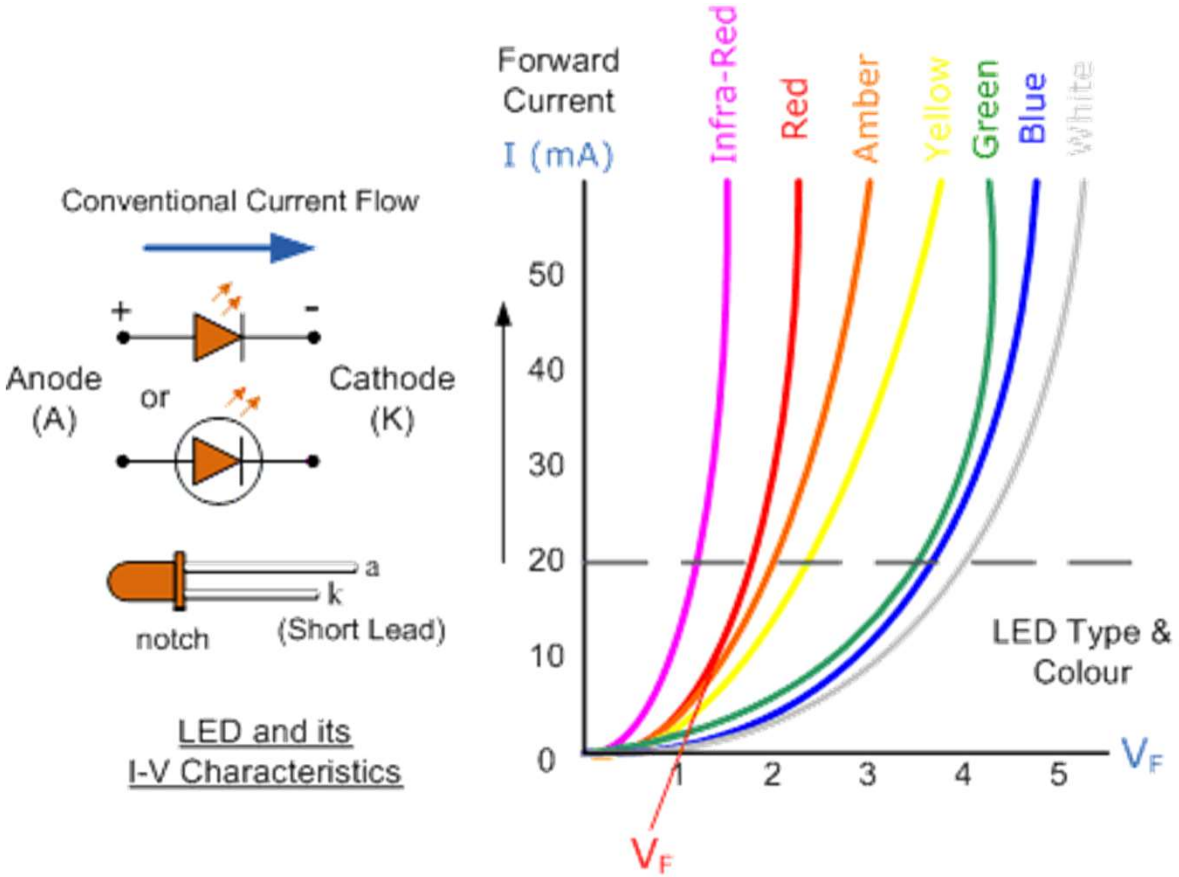

Cosmic rays
Gamma rays
X-rays
Ultra violet rays
400 NM
700 NM
Infrared rays
Micro waves
Short radio waves
Long radio waves


$10^{-6}$ nm
$10^{-5}$ nm
$10^{-4}$ nm
$10^{-3}$ nm
$10^{-2}$ nm
$10^{-1}$ nm
1 nm
10 nm
100 nm
10 nm = 1 µm
10 µm
100 µm
1000 m = 1 mm
10 mm = 1 cm
10 cm
100 cm = 1 m
10 m
100 m
1000 m = 1 km
10 km
Gamma Rays
X rays
Ultraviolet Radiation
Visible Light
Infrared Radiation
Microwaves
Radio Waves
400 nm
Violet
Blue
Green
Yellow
Orange
Red
700 nm

# Different LED's Colour

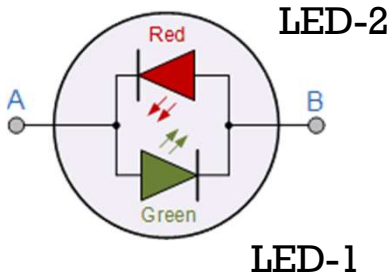
| Typical LED Characteristics | | | |
|---|---|---|---|
| Semiconductor Material | Wavelength | Colour | $V_F$ @ 20mA |
| GaAs | 850-940nm | Infra-Red | 1.2v |
| GaAsP | 630-660nm | Red | 1.8v |
| GaAsP | 605-620nm | Amber | 2.0v |
| GaAsP:N | 585-595nm | Yellow | 2.2v |
| AlGaP | 550-570nm | Green |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

# Light Emitting Diodes I-V Characteristics



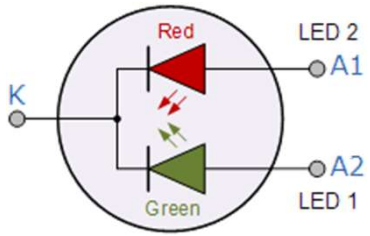

Light Emitting Diode (LED) Schematic symbol and I-V Characteristics Curves showing the different colours available

## A Bi-colour 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 |

## A Multi or Tricoloured LED




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

# 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.

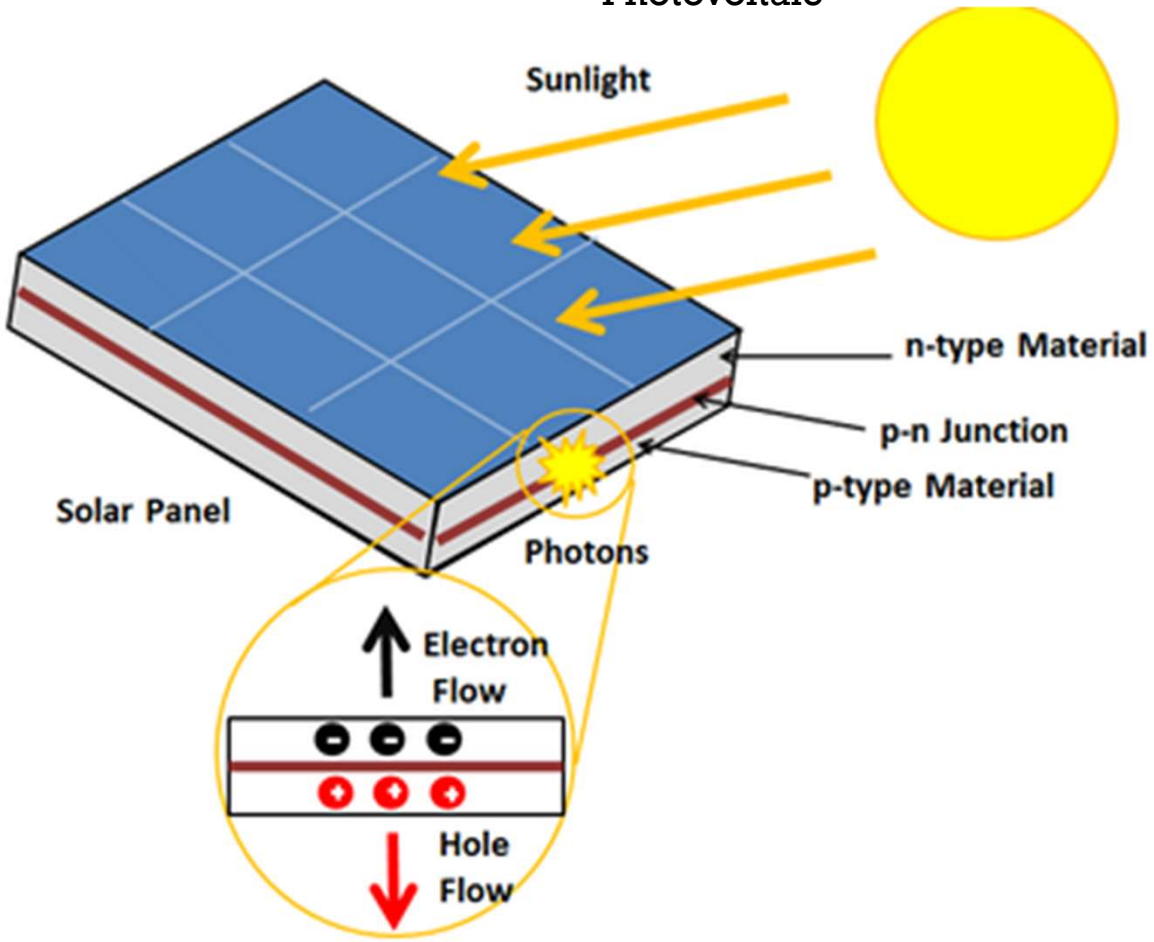
LEDs are solid-state devices:

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

# Other application of PN junction Diode

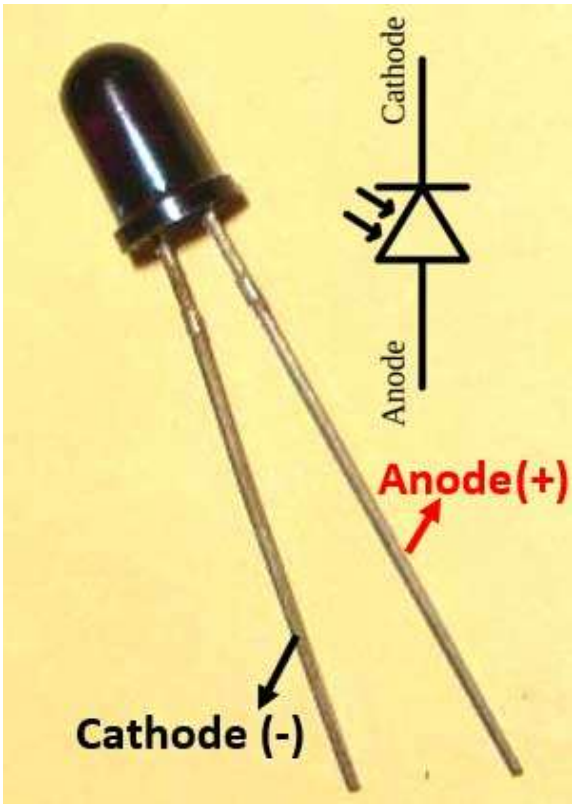
## Solar Cell

Photovoltaic




## Photo-Diode

Photo-conduction



# Thanks