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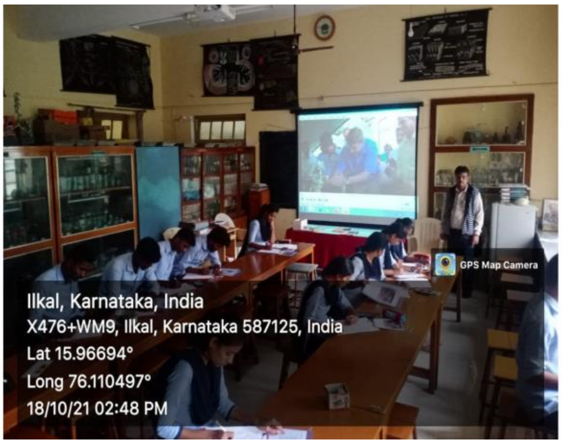

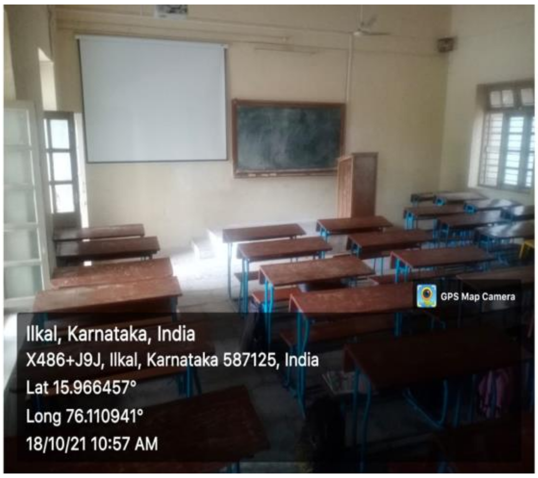

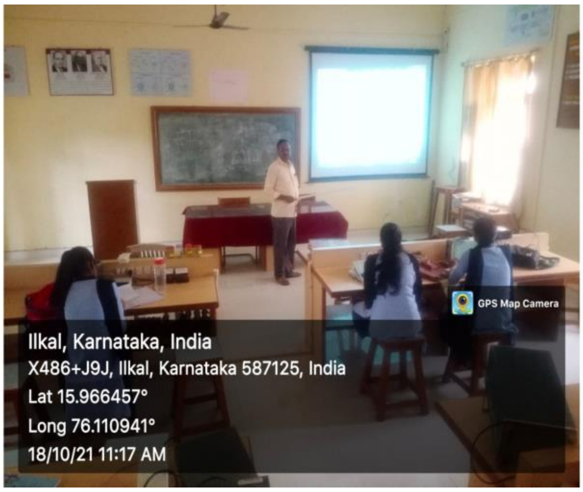


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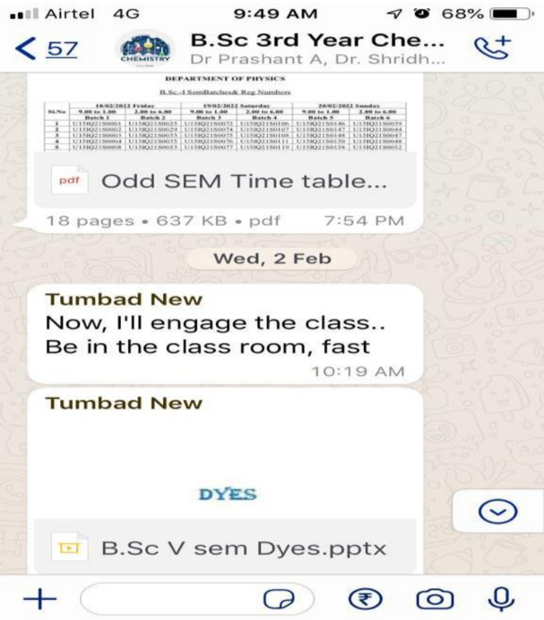

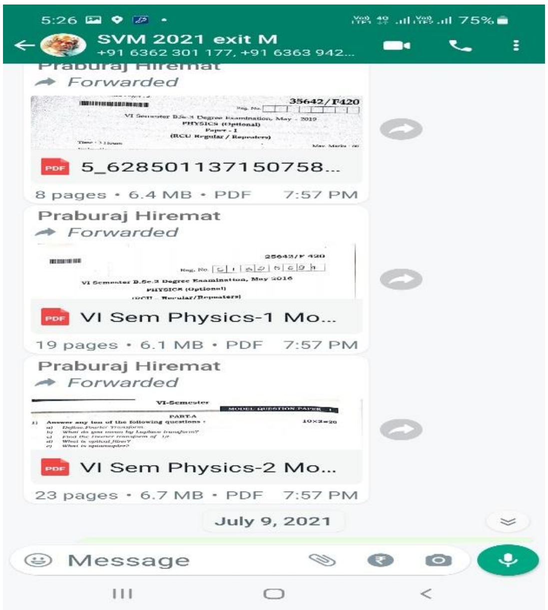

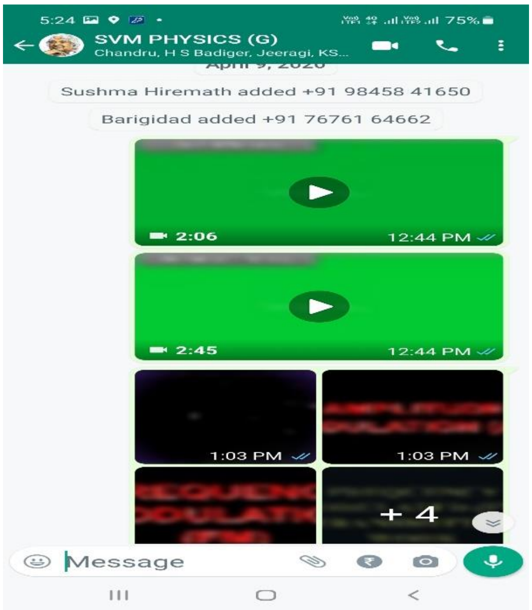

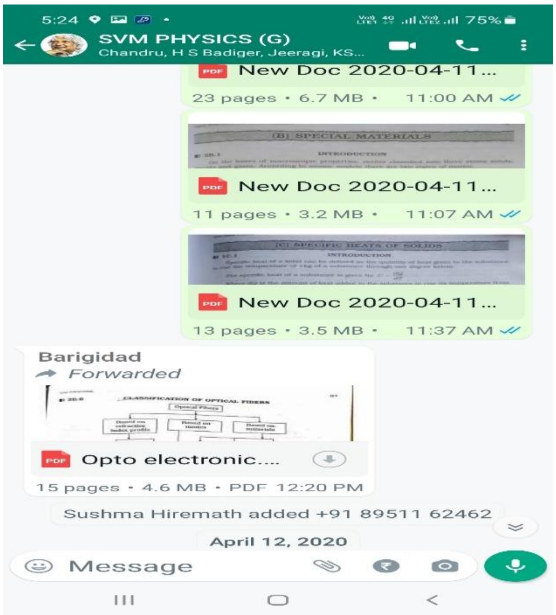

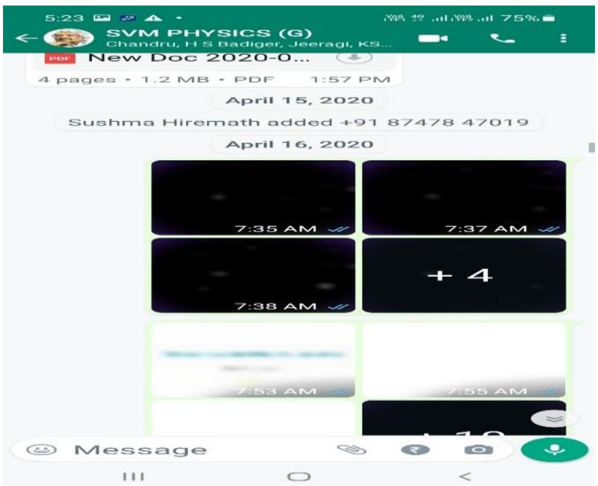

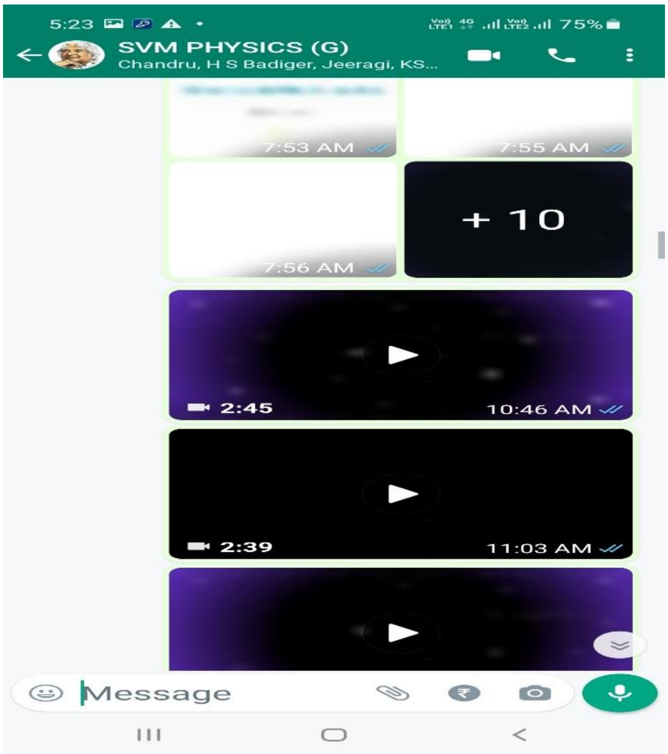
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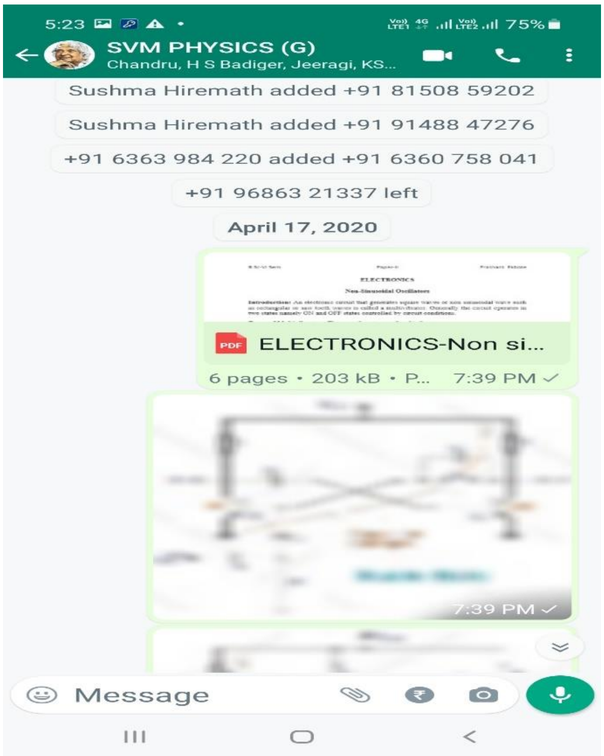
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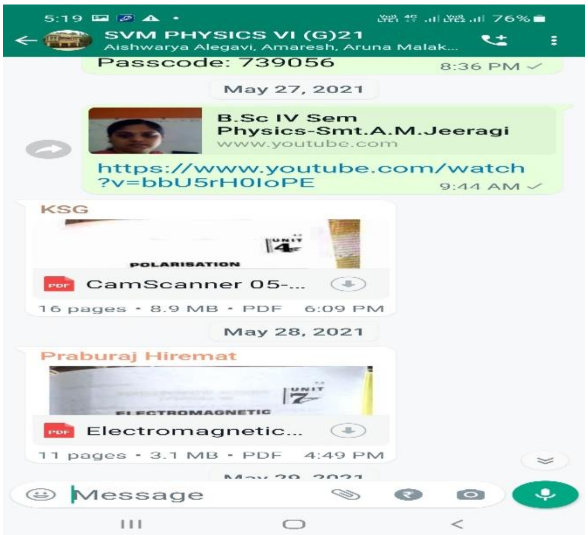
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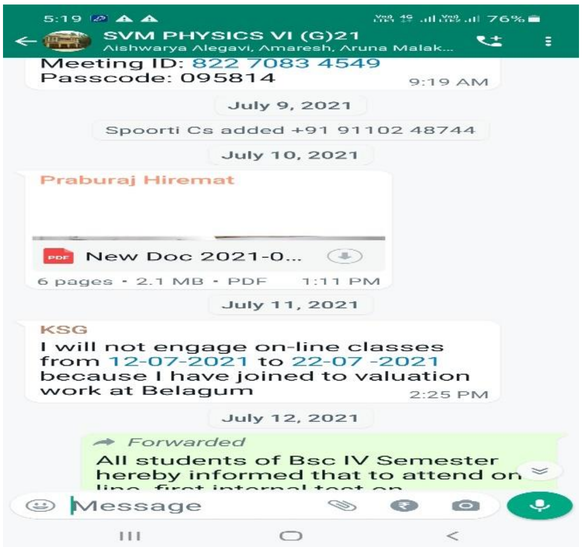
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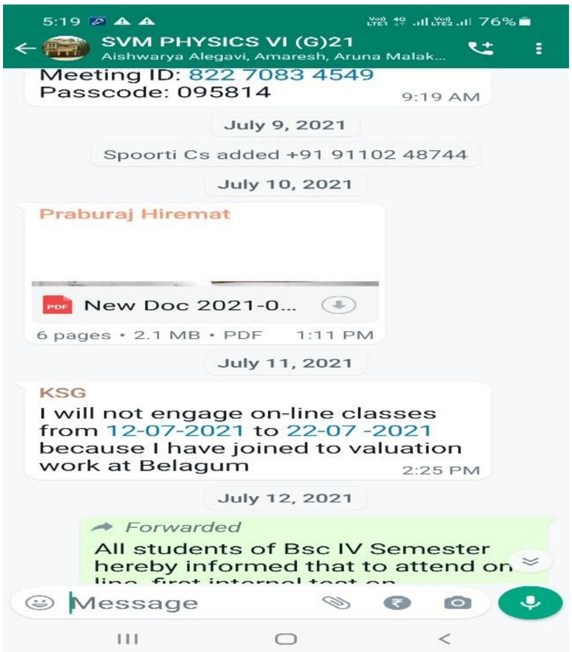
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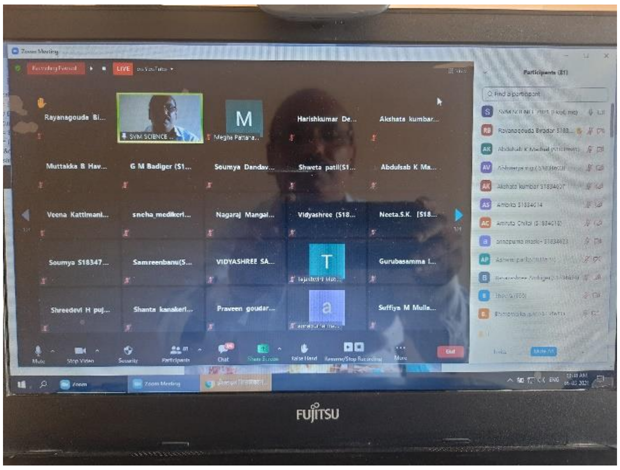

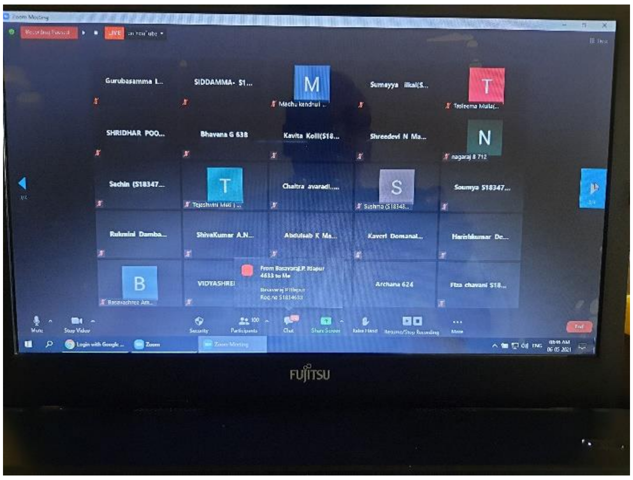

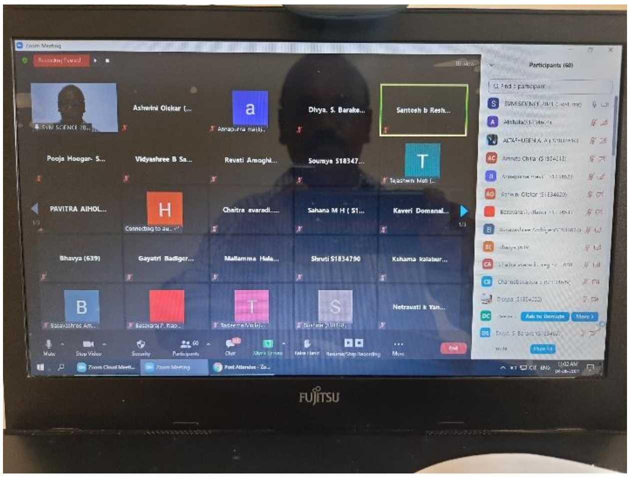

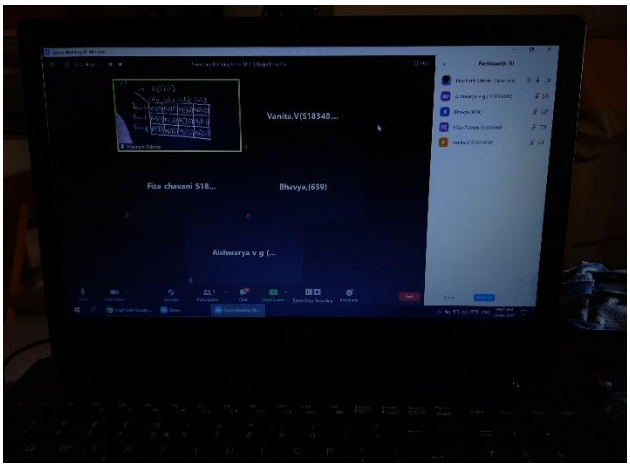

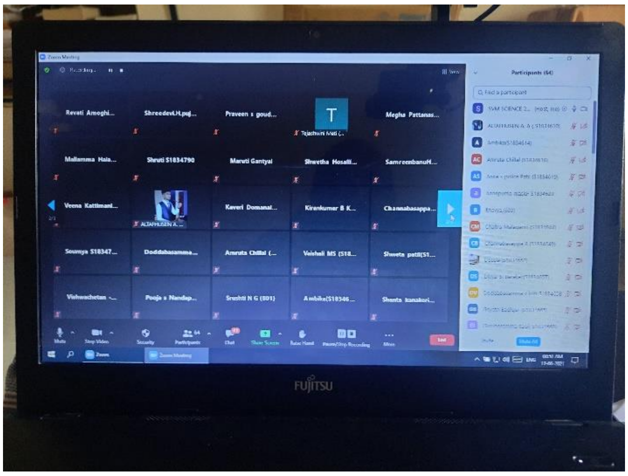

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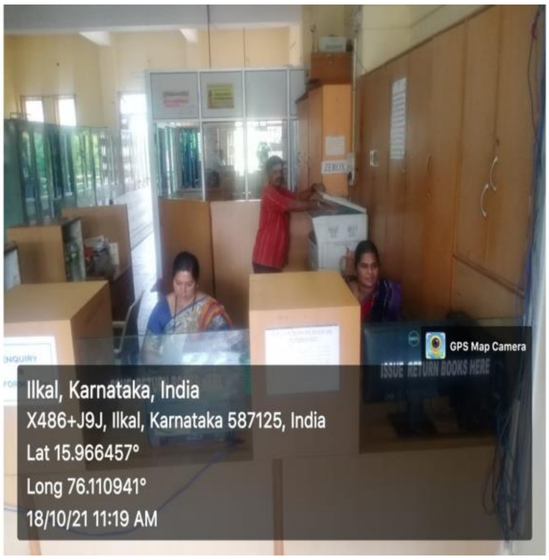
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Optoelectronics

By

K.S.Ganiger

Optoelectronics

- Introduction
- Types of optoelectronics devices
- Light Emitting Diode (LED)
    - Construction and Working
    - I-V Characteristics
- LASER Diode
    - Construction and Working
    - I-V Characteristics
- PIN Diode
- Optocoupler

Optoelectronics

Introduction

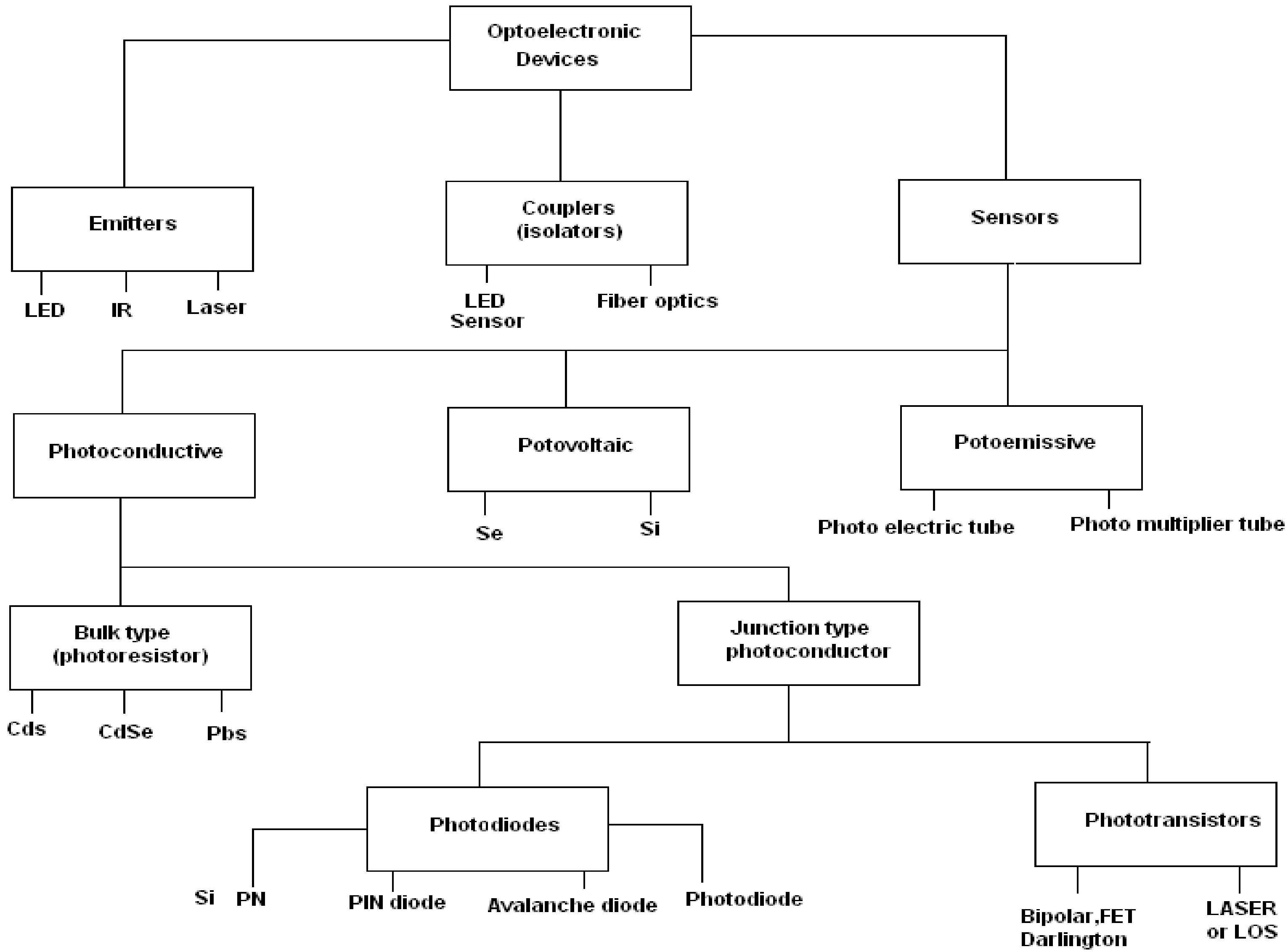
- Optoelectronics is an interesting branch of electronics that combines both electronics, and optics.
- The device based on the technology which combines optics and electronics, are called optoelectronic devices.
- The optoelectronic devices convert light (optical) energy into electrical energy or vice versa.
- Optoelectronics is based on the quantum mechanical effects of light on electronic materials, especially semiconductors, sometimes in the presence of fields.

Types of optoelectronic devices

There are three types of optoelectronic device; they are

1) Emitters
2) 2) Couplers
3) 3) Sensors.

The classification of optoelectronic devices is shown in fig below.



Light Emitting Diode

The first light emitting diode has been born. At that time, the material properties were poorly controlled, and the emission process was not well understood. The first report on LED was published by Henry Joseph Round in 1907.

Light emitting diodes are the most common light source in electronic equipment. For example, they are widely used in devices for displaying the time or other types of data on screens.

A light emitting diode is an electronic component which emits light when an electric current passes through it.

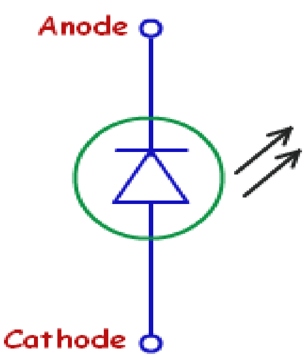
Principle: When a p-n junction is forward biased minority carriers flows in large numbers into region where they can recombine with majority carrier producing light in the visible or infra red region. The wavelength of the light is given by, $\lambda = \frac{hc}{Eg} = \frac{1.24}{Eg\,(eV)}\,\mu m$

This effect is known as injection electroluminescence. A significant light output is obtained only when there is large number of electron hole recombination's occurring per seconds. To ensure this, the p and n region are heavily doped.

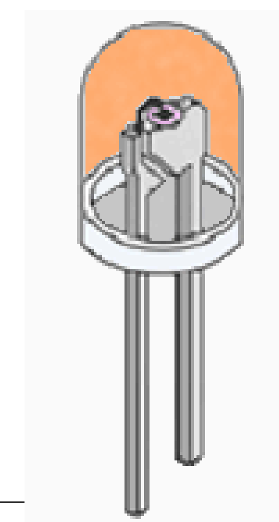
Light Emitting Diode Symbol

The figure shows the symbol of LED:

It is similar to p-n junction diode the only difference is that there are two arrows which will indicate that the diode emits the light.

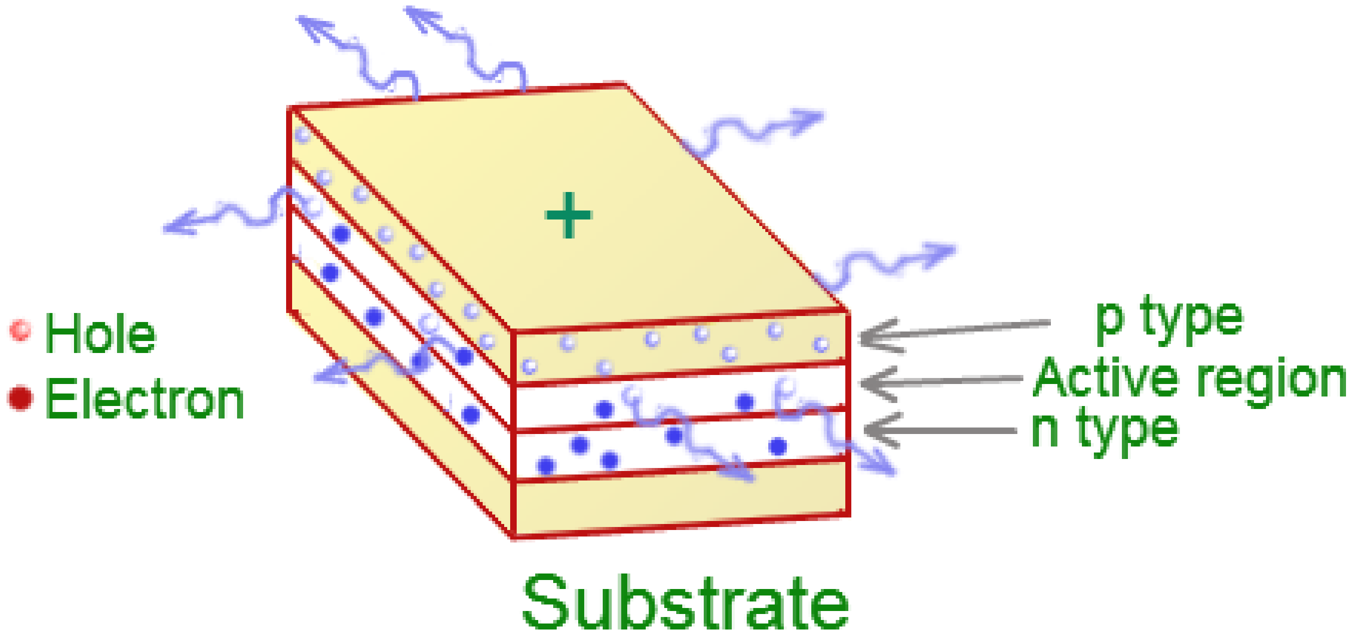


Symbol of LED



Construction of LED

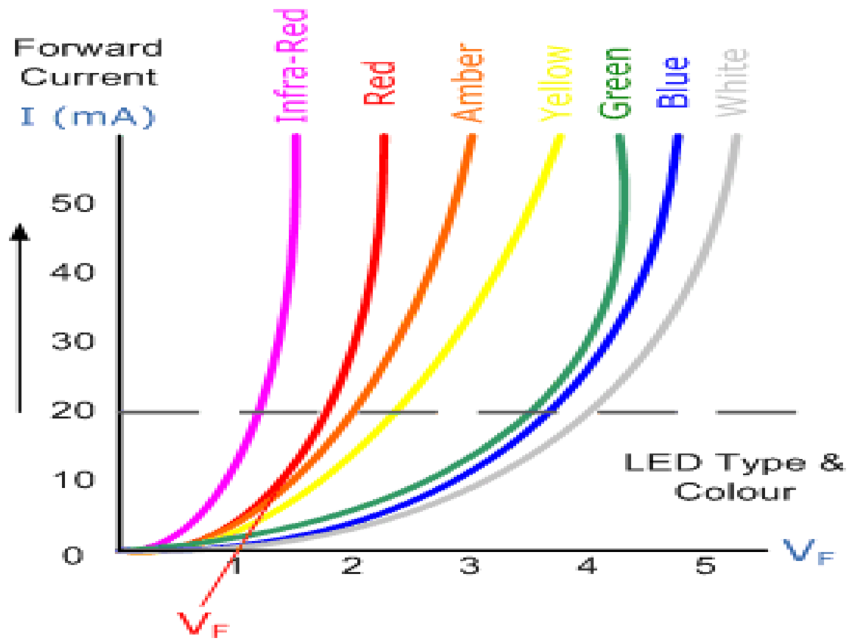
One of the method used for the LED construction is to deposit three semiconductor layers on the substrate. This is shown in figure.



In between p-type and n- type, there exists an active region. This active region emits light, when an electron and hole recombine. When the diode is forward biased, holes from p type and electrons from n type, both get driven into the active region and then the light is emitted. Light emitting diodes are available in a wide range of colours with the most common being RED,AMBER, YELLOW and GREEN and are thus widely used as visual indicators and as moving light displays.

Light Emitting Diodes I-V Characteristics.

A light emitting diode can "emit" any form of light it needs a current to flow through it, as it is a current dependant device with their light output intensity being directly proportional to the forward current flowing through the LED. As the LED is to be connected in a forward bias condition across a power supply it should be *current limited* using a series resistor to protect it from excessive current flow. Never connect an LED directly to a battery or power supply as it will be destroyed almost instantly because too much current will pass through and burn it out.Fig shows the I-V characteristics of LED for different colour LED.



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

Materials and Colours

The LED use mixtures of Gallium (Ga), Arsenic (As) and Phosphorous (P). The colour of the LED decided by the wavelength depends on forbidden energy gap. Hence different mixtures give the different colours.

- Gallium Arsenide (GaAs) - infra-red
- Gallium Arsenide Phosphide (GaAsP) - red to infra-red, orange
- Aluminium Gallium Arsenide Phosphide (AlGaAsP) - high-brightness red, orange-red, orange, and yellow
- Gallium Phosphide (GaP) - red, yellow and green
- Aluminium Gallium Phosphide (AlGaP) - green

- Gallium Nitride (GaN) - green, emerald green Gallium Indium Nitride (GaInN) - near ultraviolet, bluish-green and blue
- Silicon Carbide (SiC) - blue as a substrate
- Zinc Selenide (ZnSe) - blue
- Aluminium Gallium Nitride (AlGaN) - ultraviolet

Laser Diode

The acronym laser means light amplification by stimulated emission of radiation.
A Laser Diode is similar to an LED in many respects but it produces a narrow beam of high intensity. The radiation produced by the laser diode is of a single wavelength so that, if it is passed through glass panels it will not split into different wave-lengths. Laser diodes, developed in 1970s, have found vast commercial applications.

Properies of LASER

➢Monochromatic: It applications in different areas. The light which is coming out from a laser diode can be characterized as follows: consists of a single colour and not a mixture of colours. The spectral width of the radiated light is vey narrow.

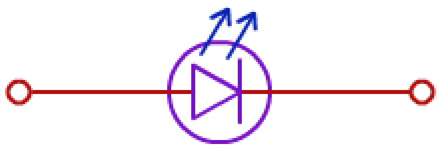
➢Well directed: It radiates a narrow, well directed beam that can be easily launched into an optical fiber.

➢Highly intense and power efficient.

➢Coherent: Coherent light means that a light with single wavelength. Since the light emitted by the LED has wide band of wave length, it is an incoherent light whereas laser light is a coherent light.

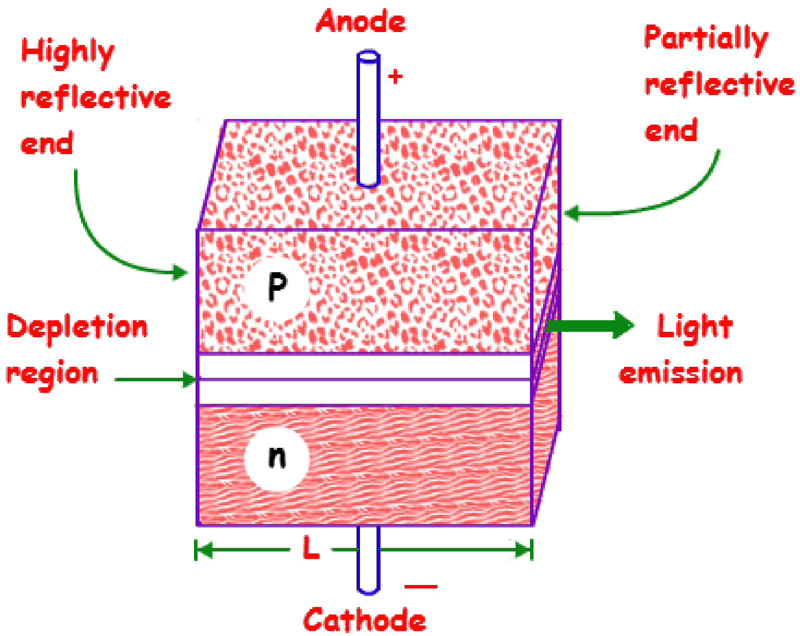
Laser Diode Symbol

The symbol of the laser diode is shown below,



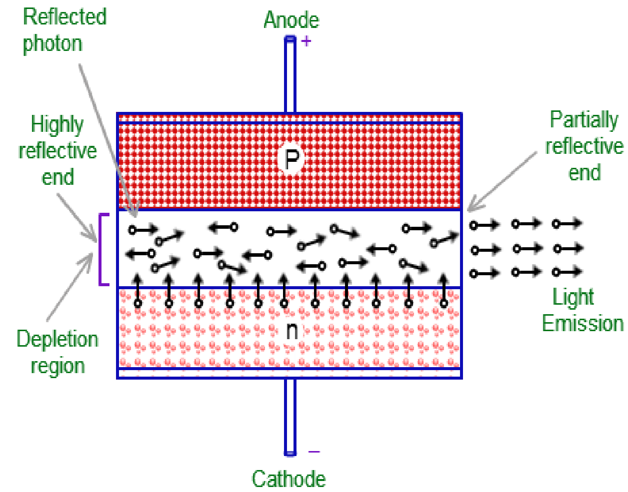
Construction of Laser Diode

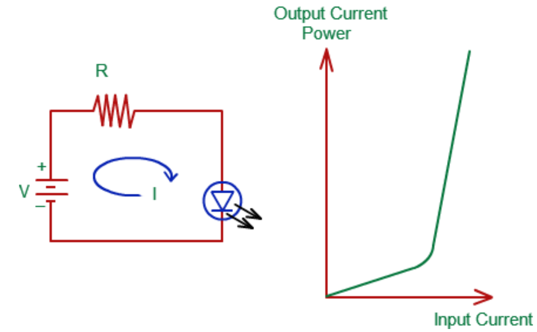
The p-n junction formed in a Laser diode by two doped gallium arsenide layers. It got two flat ends structure which is parallel with one end mirrored and one partially reflective. Wavelength of the light to be emitted is precisely related to the length of the junction.



Operation of Laser Diode

The operation of laser diode is illustrated in the given figure, When a p-n junction is forward biased by an external voltage source, the electrons move through the junction and recombines as in an ordinary diode. When electrons recombine with holes, photons are released. These photons strikes atoms, causing more photon to be released. As the forward bias current is increased, more electrons enter the depletion region and cause more photon to be emitted. Eventually some of the photons that are randomly drifting within the depletion region strike the reflected surface perpendicularly, so that they are reflected back along their original path. The reflected photons are then again reflected back from the other end of the junction. This movement of photons from one end to the another end continues for many times. During this movement of photons strike more atoms and release additional photons due to avalanche effect. This process of reflection and generation of increasing number of photons results a very intense beam of laser light. Each photons produced in the above explained emission process is identical to the other photons in energy level, phase relation and frequency. Thus emission process gives a intense beam of laser with single wavelength. To produce a beam of laser light it is necessary to have a current through the laser diode above certain threshold level. The current below threshold level forces diode to behave as LED, emitting incoherent light.





Characteristics of Laser Diode

One of the important characteristics of a laser diode is that the threshold. It is given that; the lasing action will not takes place until a minimum power is applied to the material. This is illustrated in the following figure. This graphical representation compares the output power versus the input current. Even though, the laser diodes emit the light below the threshold energy, the spontaneous emission is weaker than that of the emission of laser light above the threshold. The following graph shows the characteristics of laser diode,

Laser Diode Applications

According to the material used to form the p-n junction the laser diodes are classified. Different laser diodes got different applications.

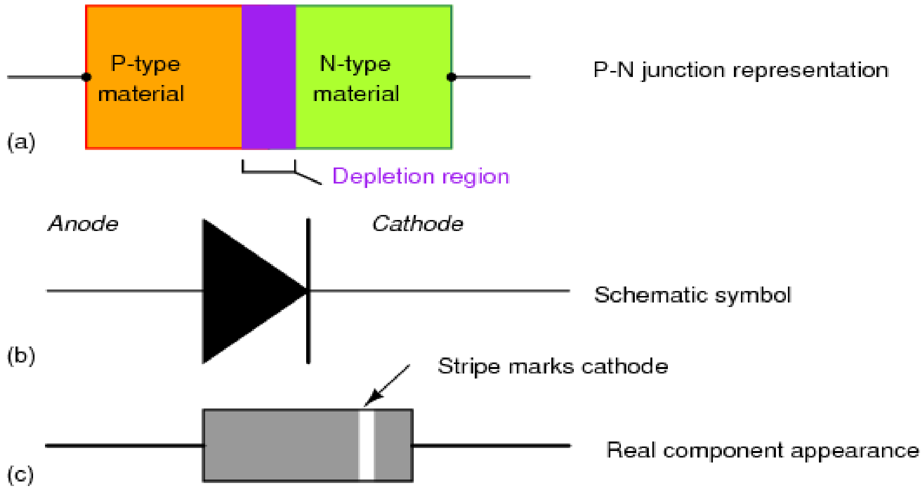
- GalnAsP – This is a diode made up of Ga,ln,As and P. which emits laser light having wavelength 1300nm. It finds applications in fiber optical communications.
- AlGaAs - This is a diode made up of Ga,Al and As. which emits laser light having wavelength 760 nm. It has been used in laser printers.
- GaAs - This is a diode made up of Ga and As. which emits laser light having wavelength 840 nm. It has been used in CD players.

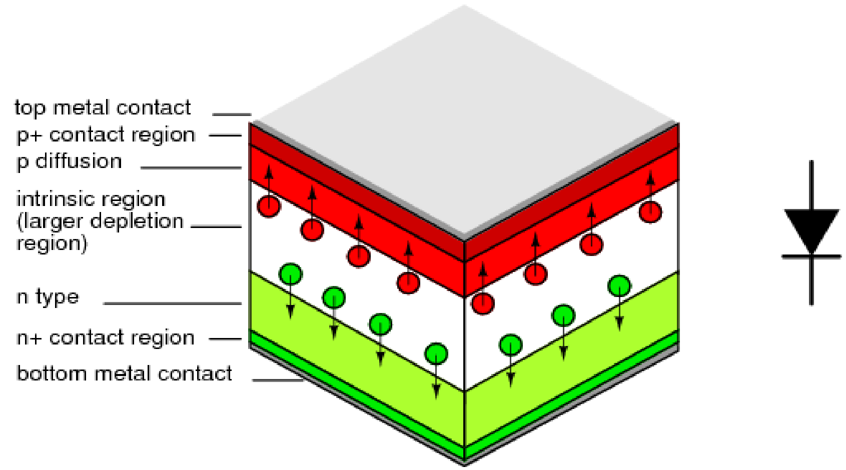
PIN diode

A PIN diode is simply a p-n junction diode that is designed to have a very small junction capacitance (0.01 to 0.1 pF) or A PIN diode is a semiconductor device that operates as a variable resistor at RF and microwave frequencies.

PIN diode operation:

The pin diode consists of two narrow, but highly doped, semiconductor regions separated by a thicker, lightly-doped material called the intrinsic region. As suggested in the name, pin, one of the heavily doped regions is p-type material and the other is n-type. The same semiconductor material, usually silicon, is used for all three areas. Silicon is used most often for its power-handling capability and because it provides a highly resistive intrinsic (i) region. The pin diode acts as an ordinary diode at frequencies up to about 100 megahertz, but above this frequency the operational characteristics change. A PIN diode operates under what is known as high-level injection. In other words, the intrinsic "i" region is flooded with charge carriers from the "p" and "n" regions. Its function can be likened to filling up a water bucket with a hole on the side. Once the water reaches the hole's level it will begin to pour out. Similarly, the diode will conduct current once the flooded electrons and holes reach an equilibrium point, where the number of electrons is equal to the number of holes in the intrinsic region. When the diode is forward biased, the injected carrier concentration is typically several orders of magnitude higher than the intrinsic level carrier concentration. Due to this high level injection, which in turn is due to the depletion process, the electric field extends deeply (almost the entire length) into the region. This electric field helps in speeding up of the transport of charge carriers from P to N region, which results in faster operation of the diode, making it a suitable device for high frequency operations.



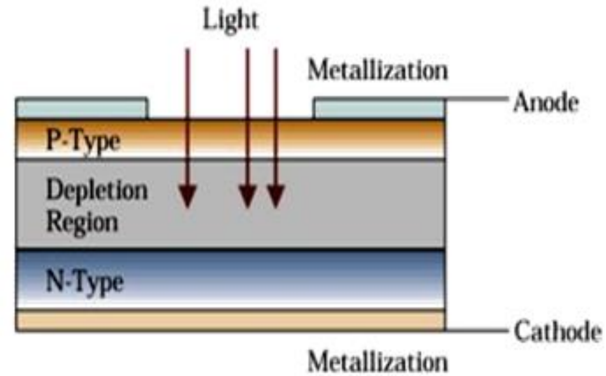


Characteristics:

A PIN diode obeys the standard diode equation for low frequency signals. At higher frequencies, the diode looks like an almost perfect (very linear, even for large signals) resistor. There is a lot of stored charge in the intrinsic region. At low frequencies, the charge

can be removed and the diode turns off. At higher frequencies, there is not enough time to remove the charge, so the diode never turns off. The PIN diode has a poor reverse recovery time. The high-frequency resistance is inversely proportional to the DC bias current through the diode. A PIN diode, suitably biased, therefore acts as a variable resistor. This high-frequency resistance may vary over a wide range (from 0.1 ohm to 10 kΩ in some cases; the useful range is smaller, though).The wide intrinsic region also means the diode will have a low capacitance when reverse biased. In a PIN diode, the depletion region exists almost completely within the intrinsic region. This depletion region is much larger than in a PN diode, and almost constant-size, independent of the reverse bias applied to the diode. This increases the volume where electron-hole pairs can be generated by an incident photon. Some photo detector devices, such as PIN photodiodes and phototransistors (in which the base-collector junction is a PIN diode), use a PIN junction in their construction.The diode design has some design tradeoffs. Increasing the dimensions of the intrinsic region (and its stored charge) allows the diode to look like a resistor at lower frequencies. It adversely affects the time needed to turn off the diode and its shunt capacitance. PIN diodes will be tailored for a particular use.

Applications of PIN diode: PIN diodes are used as
•RF switches,
•Attenuators, and
Photo detectors.



Avalanche Photodiode

An avalanche photodiode is a silicon based semiconductor containing a **pn** junction consisting of a positively doped **p** region and a negatively doped **n** region sandwiching an area of neutral charge termed the **depletion region**. These diodes provide gain by the generation of electron-hole pairs from an energetic electron that creates an "avalanche" of electrons in the substrate. The avalanche photodiode (APD) is also operated in the reverse bias mode.

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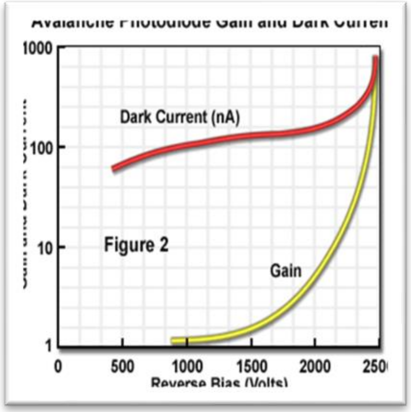
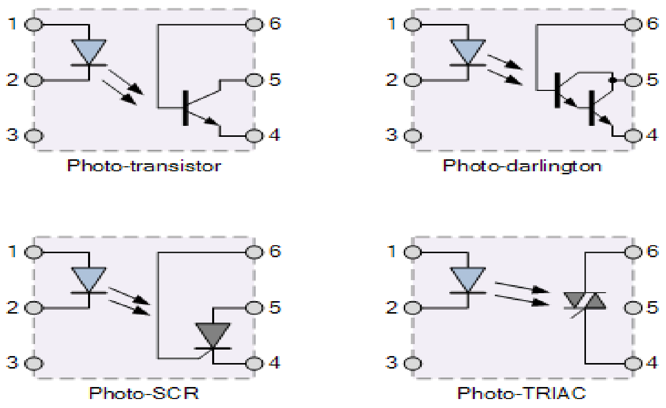
Avalanche photodiodes are capable of modest gain (500-1000), but exhibit substantial dark current, which increases markedly as the bias voltage is increased (see Figure 2). They are compact and immune to magnetic fields, require low currents, are difficult to overload, and have a high quantum efficiency that can reach 90 percent. Avalanche photodiodes are now being used in place of photomultiplier tubes for many low-light-level applications.

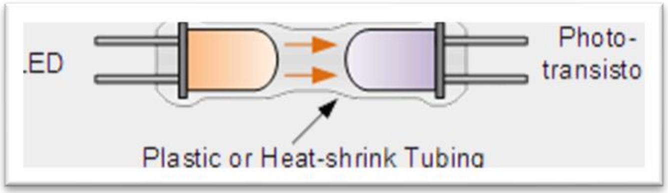


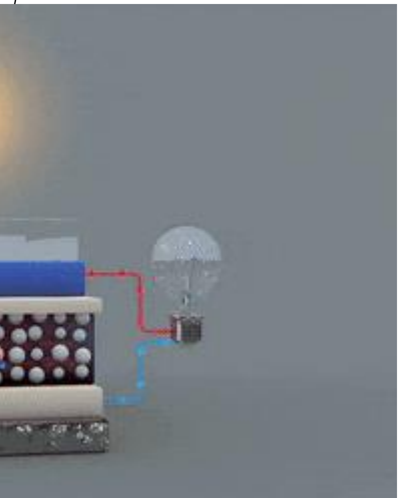
Optocoupler:

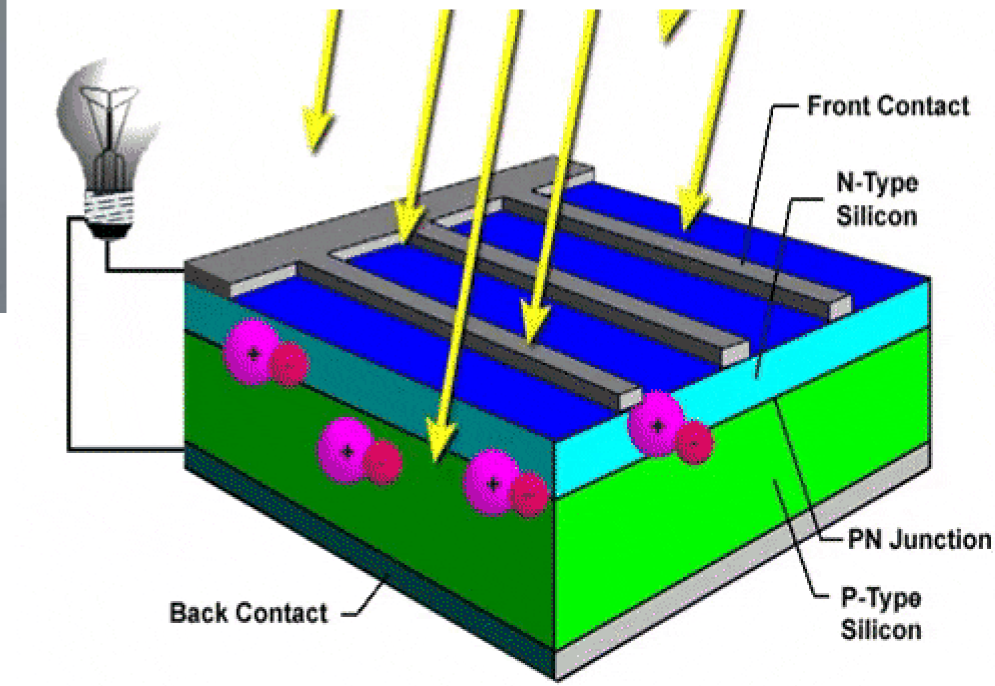
An **Optocoupler**, also known as an **Opto-isolator** or **Photo-coupler**, are electronic components that interconnect two electrical circuits by means of an optical interface. The basic design of an optocoupler consists of an LED that produces infra-red light and a semiconductor photo-sensitive device that is used to detect this emitted infra-red light. Both the LED and photo-sensitive device are enclosed in a light-tight body or package with metal legs for the electrical connections as s n.

Types of Optocouplers: Optocouplers are available in four general types, each one having an infra-red LED source but with different photo-sensitive devices. The four optocouplers are: photo-transistor, photo-darlington, photo-SCR and photo-triac as shown below.
The photo-transistor and photo-darlington devices are mainly for use in DC circuits while the photo-SCR and photo-triac allow AC powered circuits to be controlled. There are many other kinds of source-sensor combinations, such as LED-photodiode, LED-LASER, lamp-photo ---resistor pairs, reflective and slotted optocouplers.
Simple homemade optocouplers can be constructed by using individual components. An Led and a photo-transistor are inserted into a rigid plastic tube or encased in heat-shrinkable tubing as shown. The tubing can be of any length.

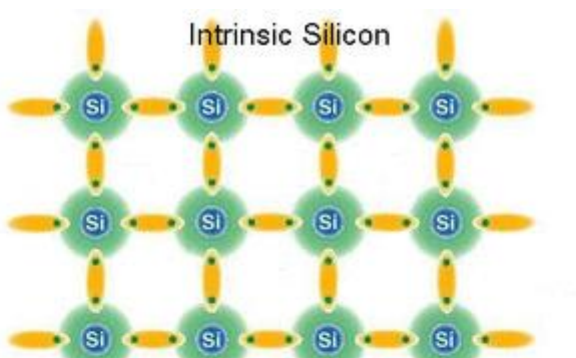


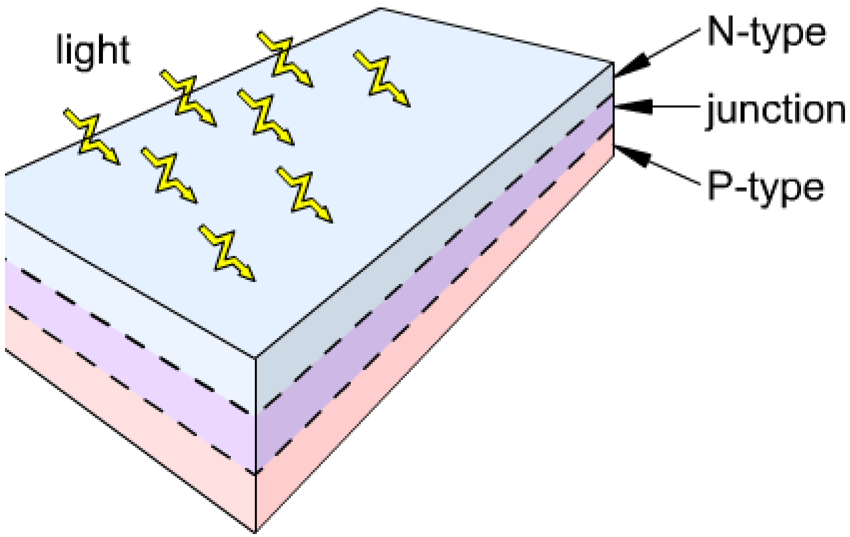


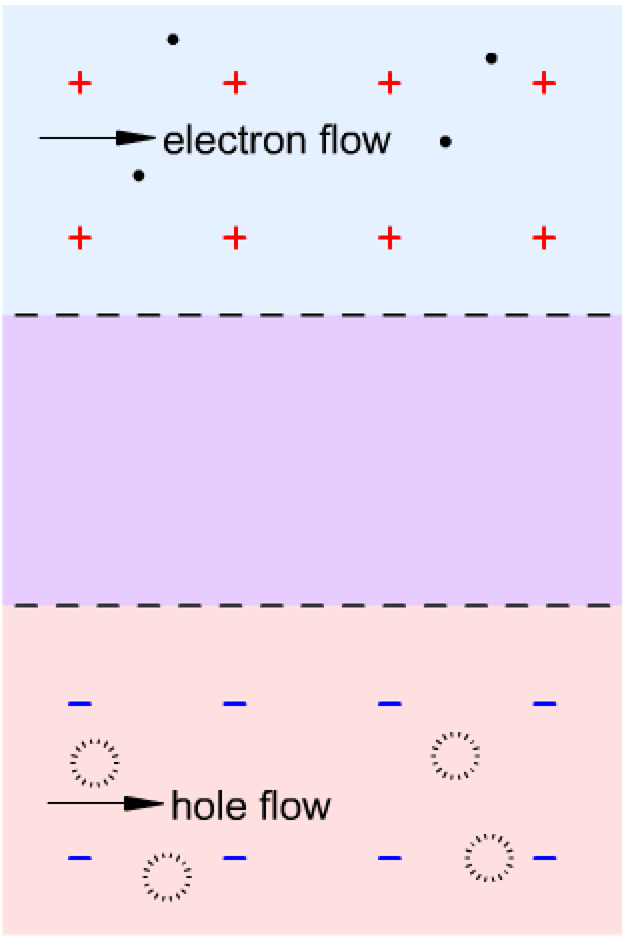


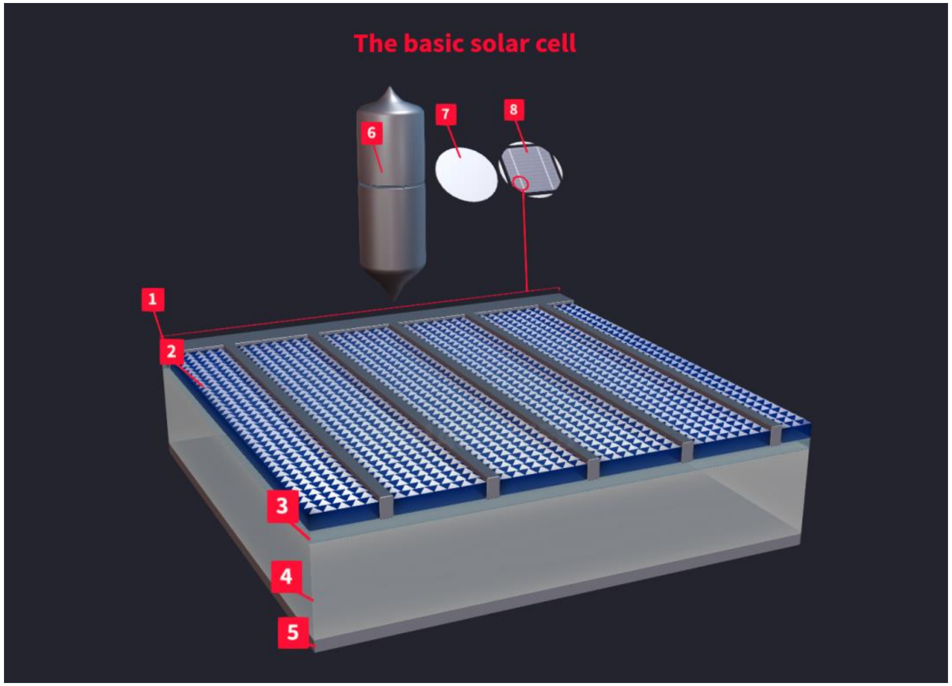

Front Contact
N-Type
Silicon
PN Junction
P-Type
Silicon
Back Contact

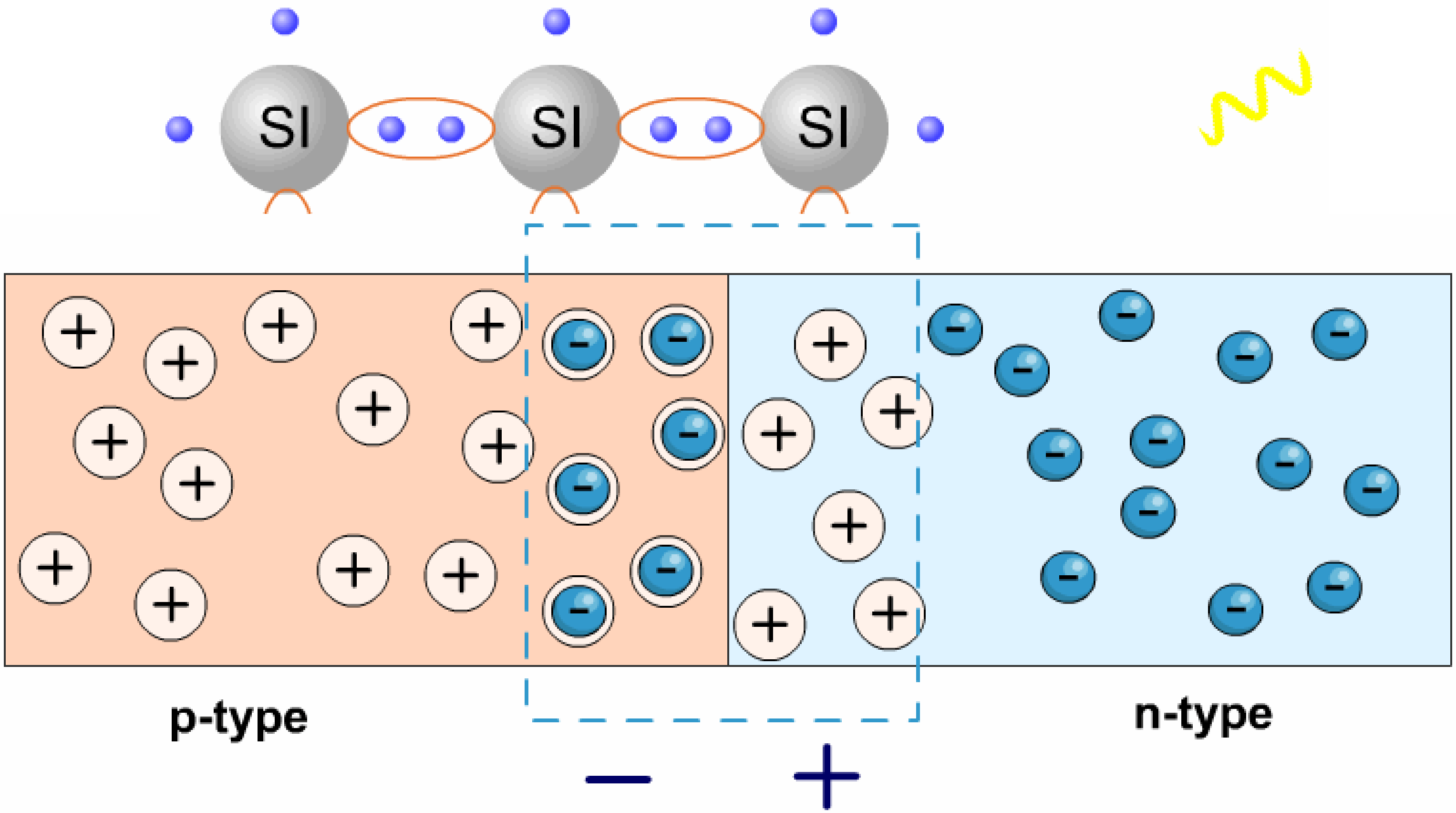

1


Intrinsic Silicon
Si


light
N-type
junction
P-type


electron flow
hole flow


The basic solar cell
1
2
3
4
5
6
7
8

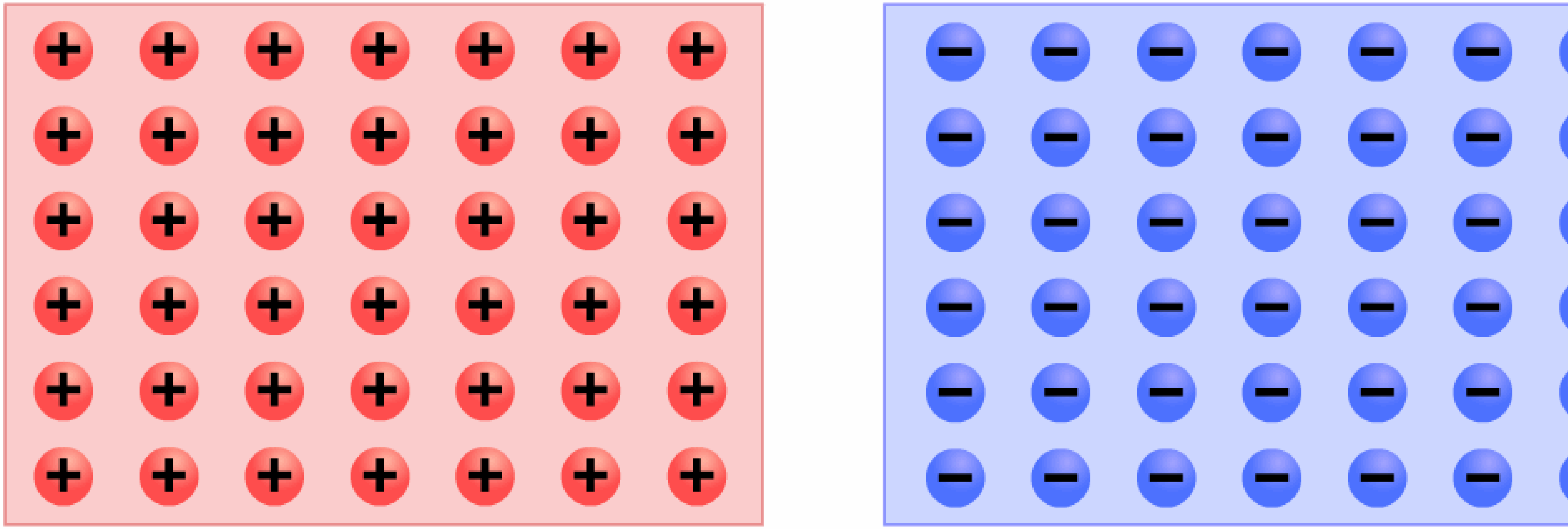


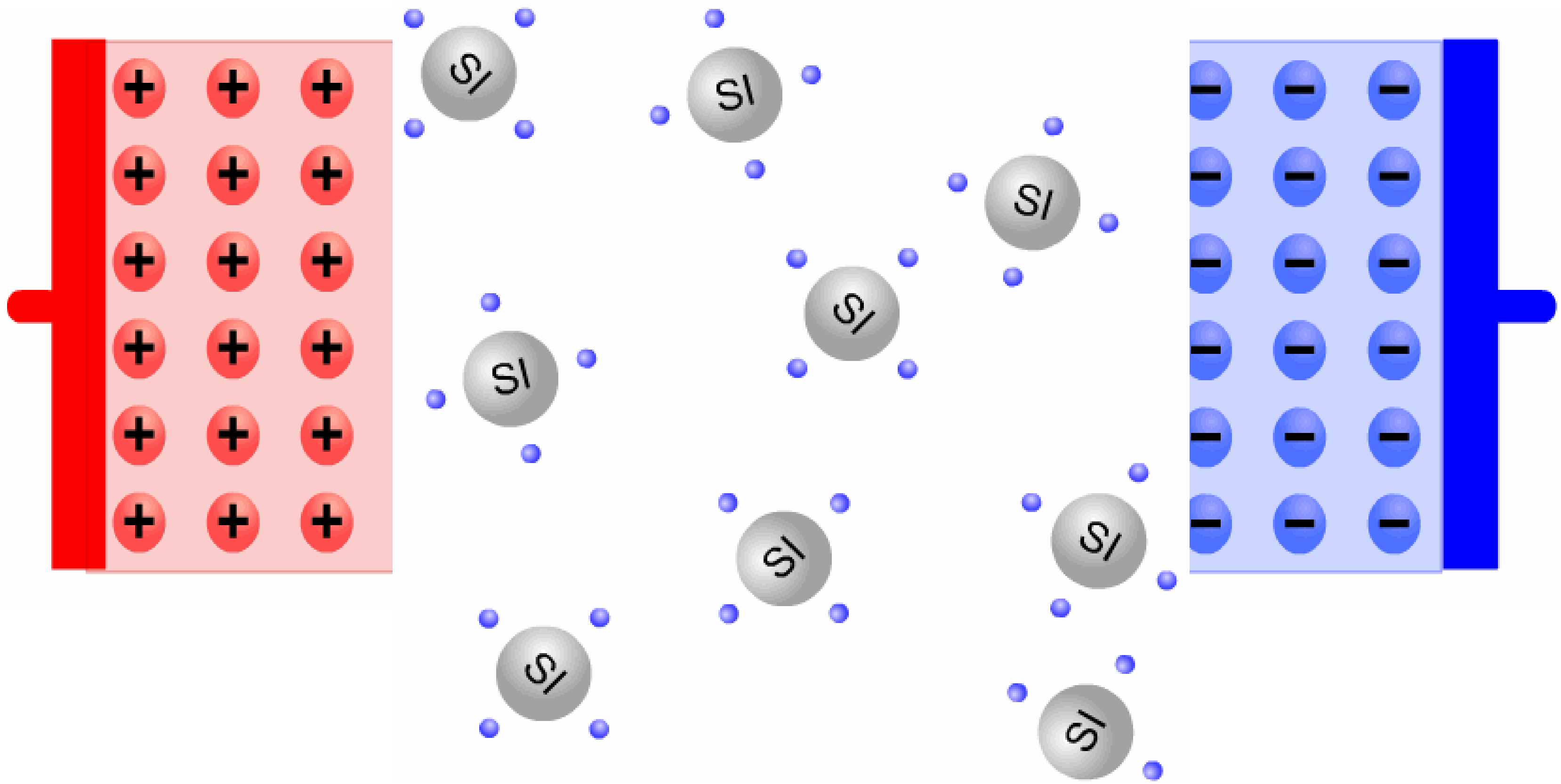
-Semiconductors n-type and p-type are brought together

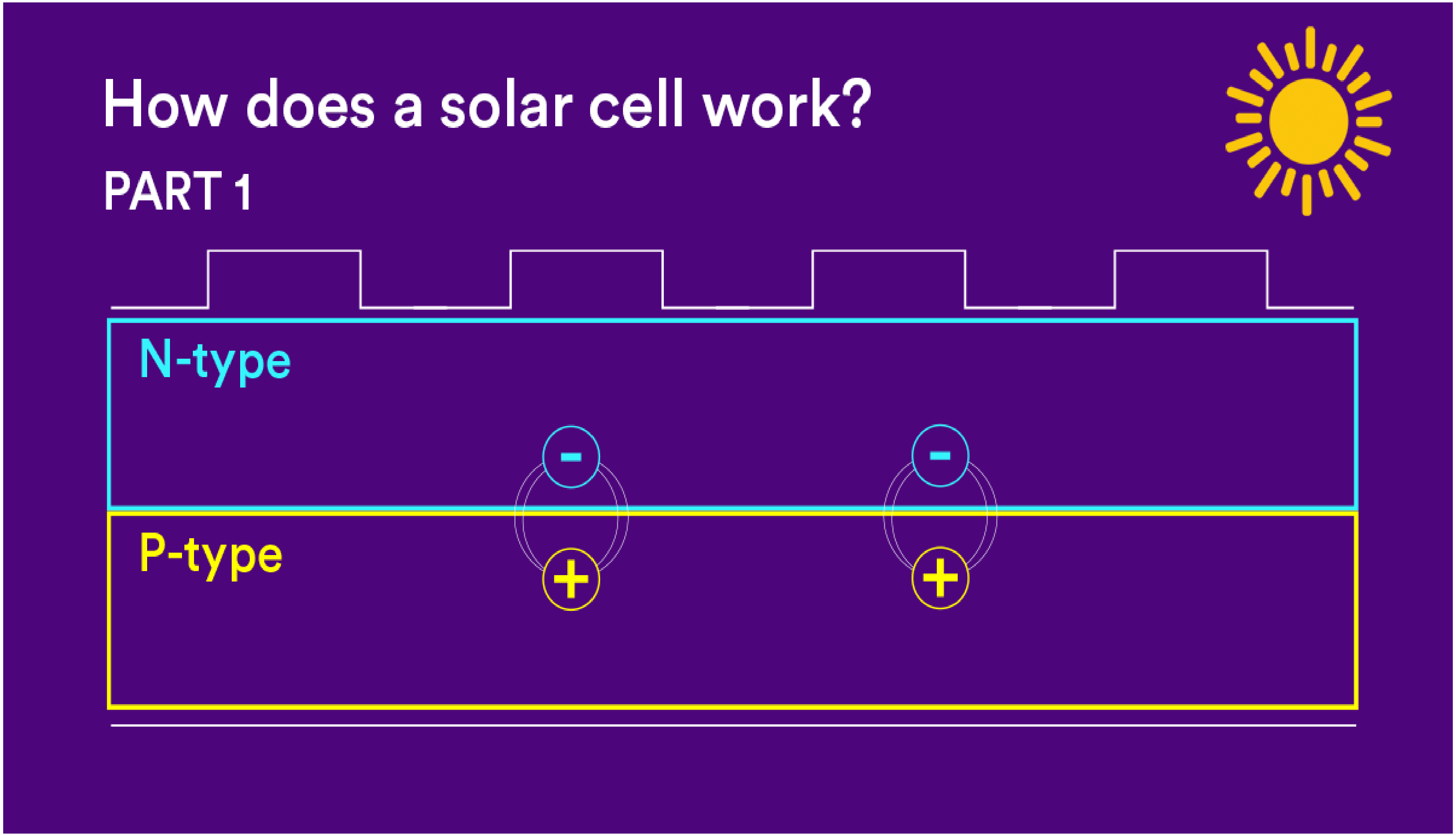
-Electrons and holes migrate across the junction

-The depletion layer is formed

-A p.d. is set up across the depletion layer

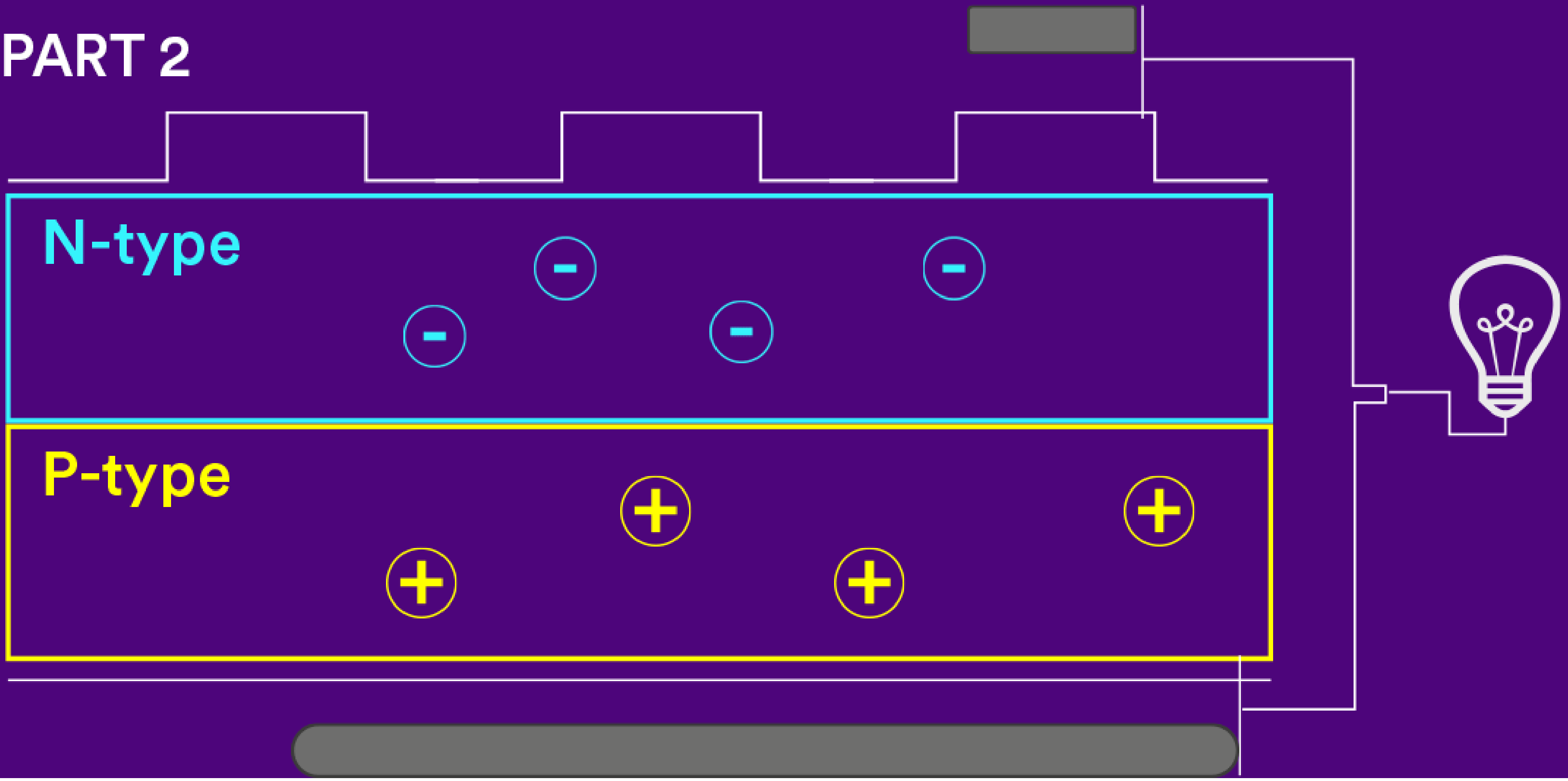


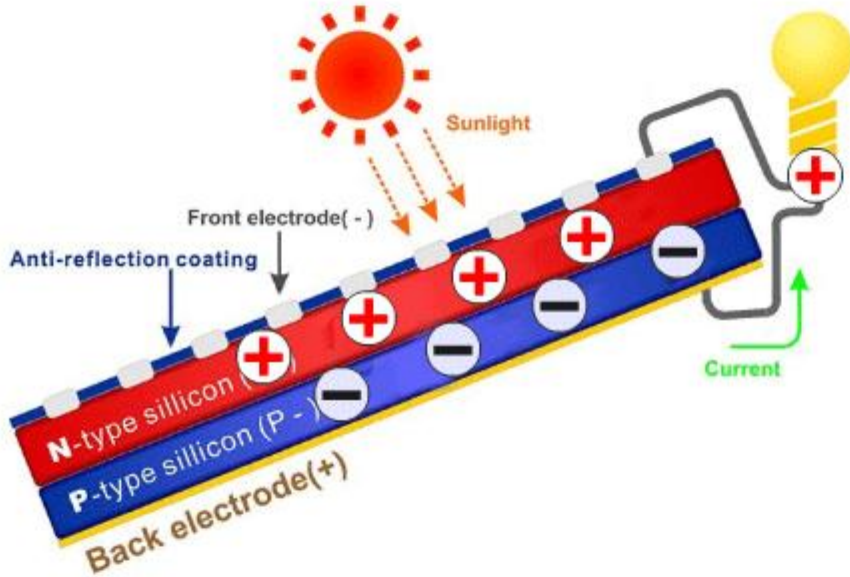

Si
Si
Si
Si
Si
Si
Si
Si
Si


How does a solar cell work?
PART 1
N-type
P-type

How does a solar cell work?

PART 2




Sunlight
Front electrode(-)
Anti-reflection coating
N-type sillicon (
P-type sillicon (P -)
Back electrode(+)
Current