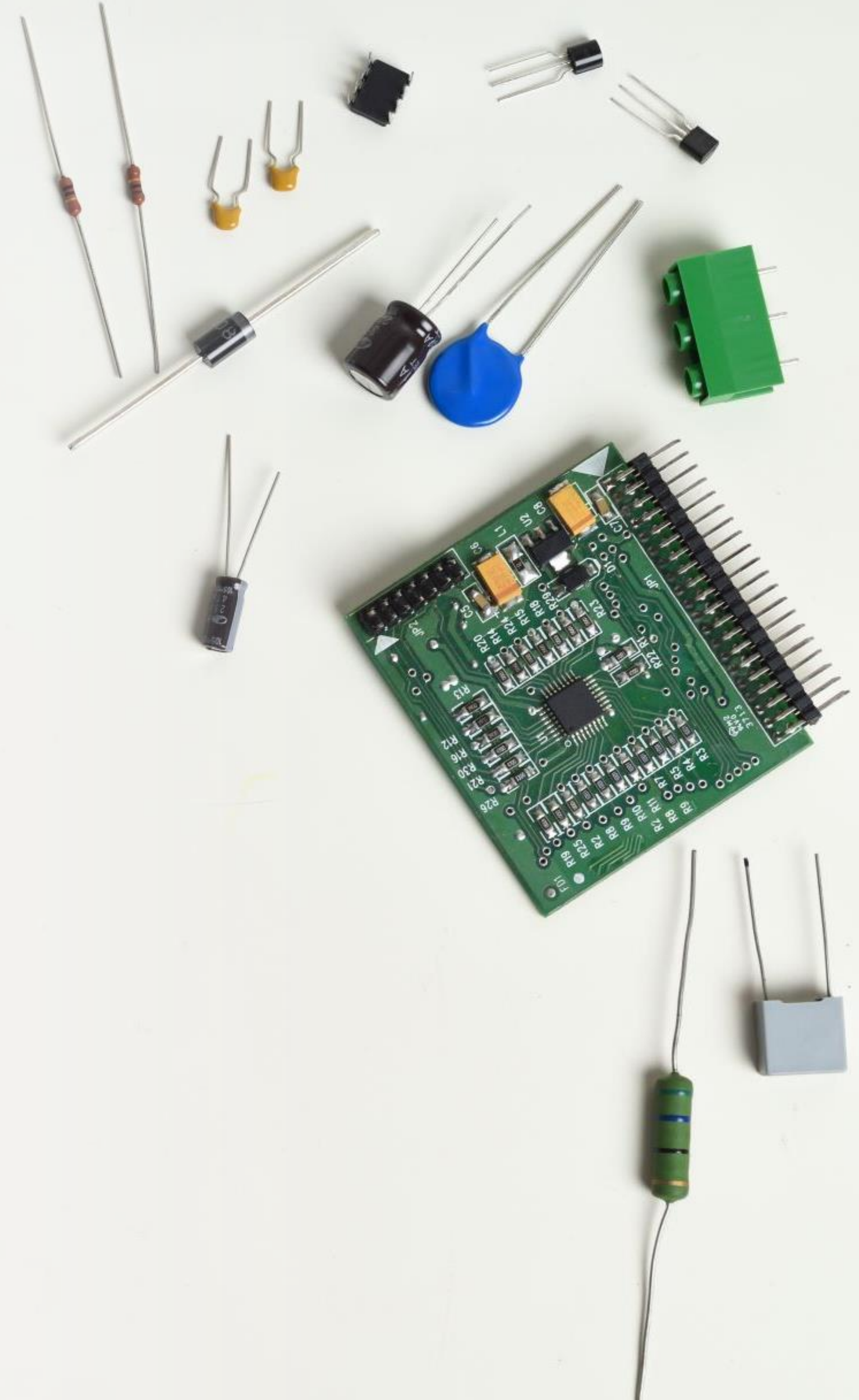
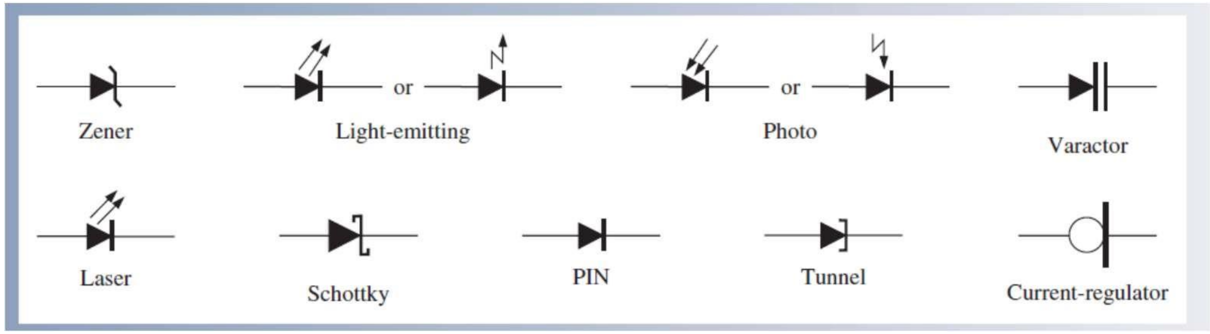
104010 : BASIC ELECTRONICS ENGINEERING

UNIT I

Introduction to Electronics



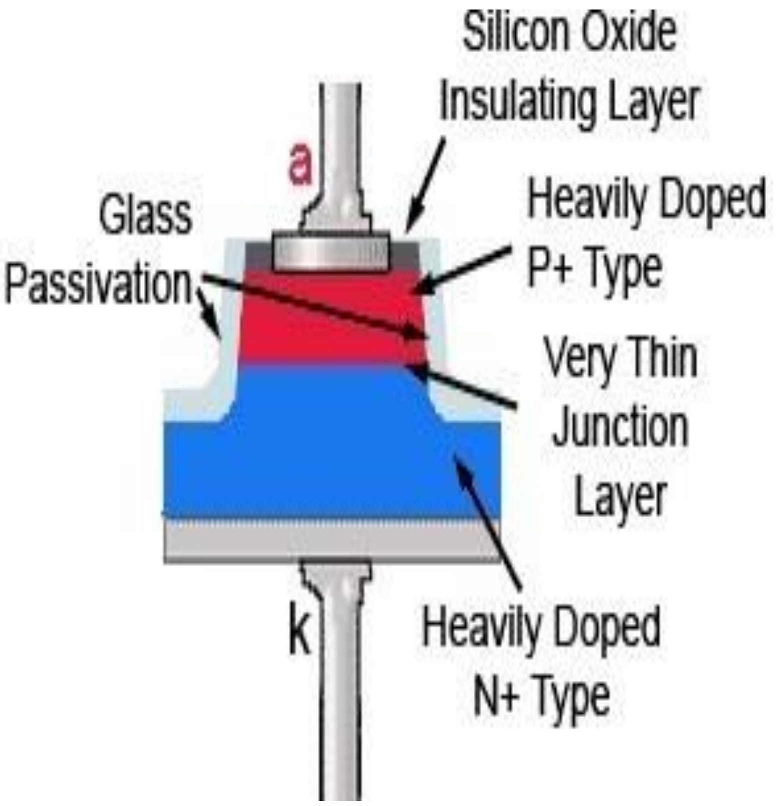
Special Purpose Diodes



- Zener Diode
- Light Emitting Diode
- Photo Diode
- V-I Characteristics

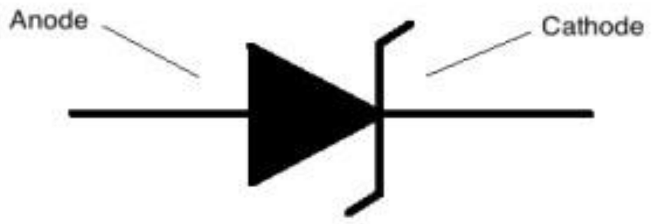
Zener Diode

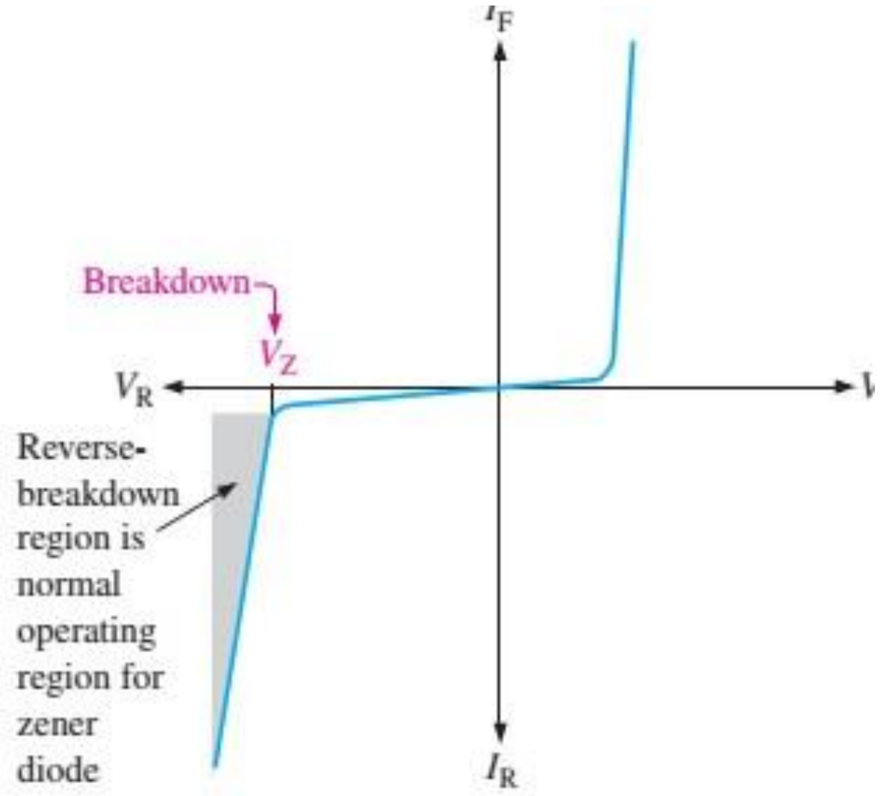
- Zener diodes are a modified form of PN silicon diode.
- The P type and N type silicon used is doped more heavily than a standard PN junction diode.
- This results in a relatively thin junction layer, and consequently a reverse breakdown voltage that can be much lower than in a conventional diode.
- The actual breakdown voltage is controlled during manufacture by adjusting the amount of doping used.
- Breakdown voltages can be selected in this way to occur at precise preset values anywhere between about 3V and 300V.
- Zener diodes can also withstand higher reverse current flow than comparable PN diodes, and are available with various power ratings, typically from 500mW to 50W.



Zener Diode

- A zener diode is a silicon pn junction device that is designed for operation in the reverse-breakdown region.
- The breakdown voltage of a zener diode is set by carefully controlling the doping level during manufacture.





Zener Breakdown

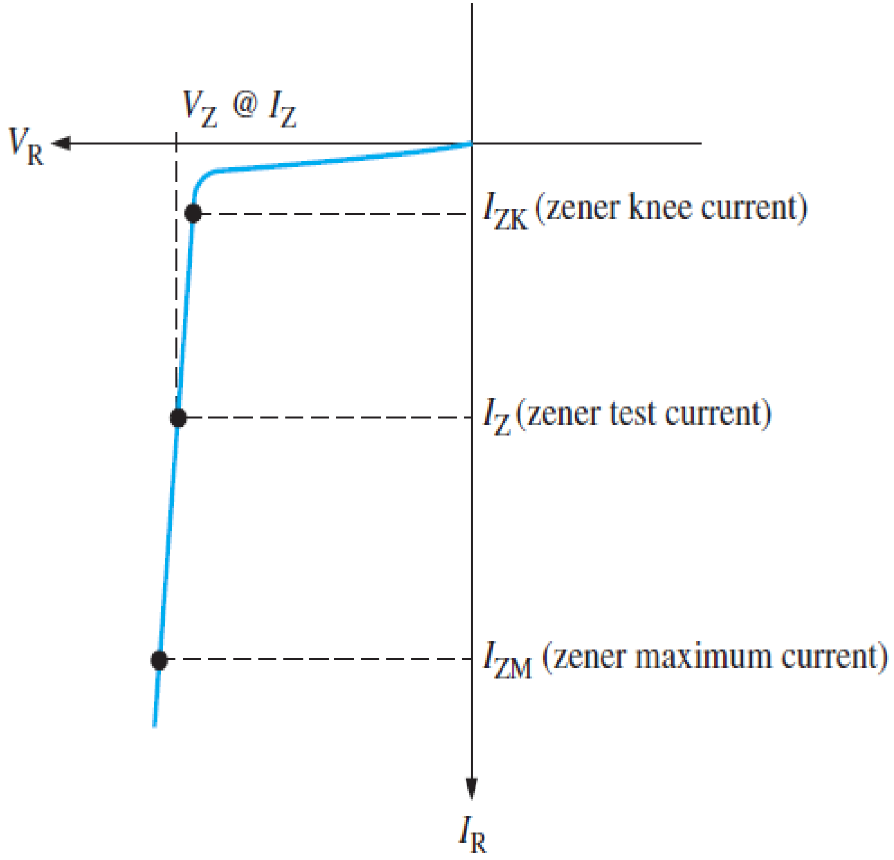
- Zener diodes are designed to operate in reverse breakdown. Two types of reverse breakdown in a zener diode are **avalanche and zener**. The avalanche effect, occurs in both rectifier and zener diodes at a sufficiently high reverse voltage. Zener breakdown occurs in a zener diode at low reverse voltages. A zener diode is heavily doped to reduce the breakdown voltage.
- This causes a very thin depletion region. As a result, an intense electric field exists within the depletion region. Near the zener breakdown voltage (V_Z), the field is intense enough to pull electrons from their valence bands and create current.
- Zener diodes with breakdown voltages of less than approximately 5 V operate predominately in zener breakdown. Those with breakdown voltages greater than approximately 5 V operate predominately in avalanche breakdown. Both types, however, are called zener diodes.

Avalanche Breakdown

- In Zener diodes with wider depletion layers, higher breakdown voltages, the increase in current at the breakdown voltage is much more sudden.
- An abrupt reduction in the reverse resistance of the diode and a nearly vertical region to the diode´s reverse current characteristic.
- This effect happens mainly in diodes with a higher reverse breakdown voltage (above about 5V) and less heavily doped P and N regions.
- Below the reverse breakdown voltage, although only a small reverse leakage current is flowing, some current does flow and therefore electrons and holes are entering the depletion layer.
- As the reverse voltage approaches the reverse breakdown voltage the electrons and holes entering the depletion layer come under the effect of a strong electric field and are rapidly accelerated.
- In this accelerated state they begin to collide with other atoms and knock electrons from their atomic bonds in a process called 'impact ionisation', so creating more electron/hole pairs that are also greatly accelerated by the electric field.
- These secondary current carriers in turn ionise other atoms, creating a very rapid increase in reverse current through the diode. This process is called 'Avalanche Breakdown'.

Breakdown Characteristics

- Figure shows the reverse portion of a zener diode's characteristic curve. Notice that as the reverse voltage (V_R) is increased, the reverse current (I_R) remains extremely small up to the "knee" of the curve. The reverse current is also called the zener current, I_Z.
- At this point, the breakdown effect begins; the internal zener resistance, also called zener impedance (Z_Z), begins to decrease as the reverse current increases rapidly.
- From the bottom of the knee, the zener breakdown voltage (V_Z) remains essentially constant although it increases slightly as the zener current, I_Z, increases.

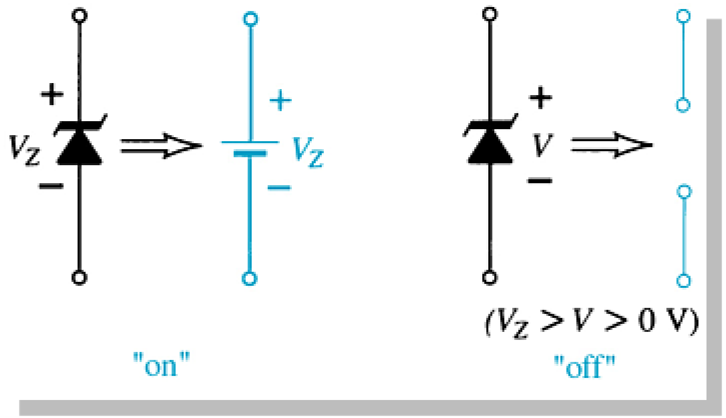


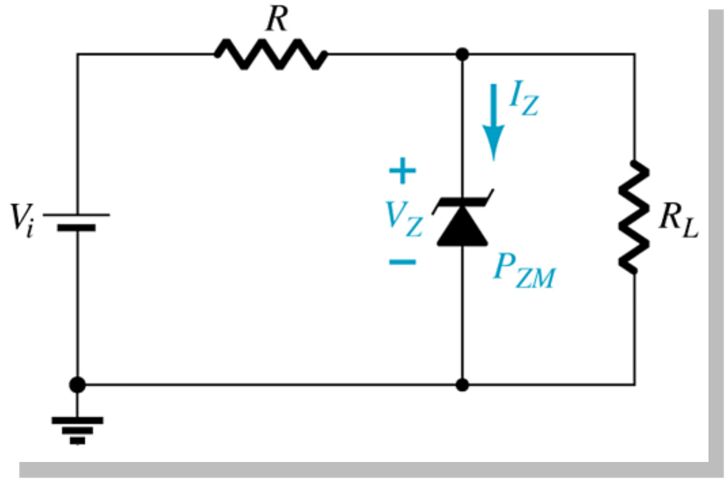
Zener Diode

The Zener is a diode operated in reverse bias at the Zener Voltage (V_z).

- When $V_i \geq V_Z$
  - The Zener is on
  - Voltage across the Zener is V_Z
  - Zener current: $I_Z = I_R – I_{RL}$
  - The Zener Power: $P_Z = V_Z I_Z$

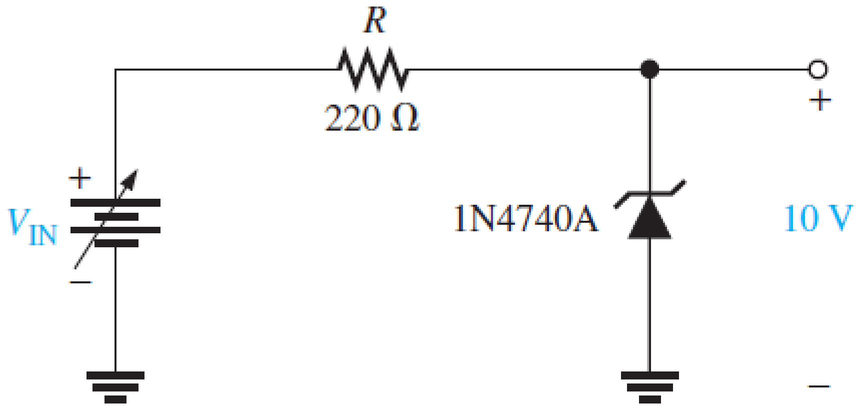
- When $V_i < V_Z$
  - The Zener is off
  - The Zener acts as an open circuit





Zener Regulation with Variable Input Voltage

- Zener diode regulators can provide a reasonably constant dc level at the output, but they are not particularly efficient. For this reason, they are limited to applications that require only low current to the load.
- The figure illustrates how a zener diode can be used to regulate a dc voltage. As the input voltage varies (within limits), the zener diode maintains a nearly constant output voltage across its terminals. However, as V_{IN} changes, I_Z will change proportionally so that the limitations on the input voltage variation are set by the minimum and maximum current values (I_{ZK} and I_{ZM}) with which the zener can operate.
- Resistor R is the series current-limiting resistor.

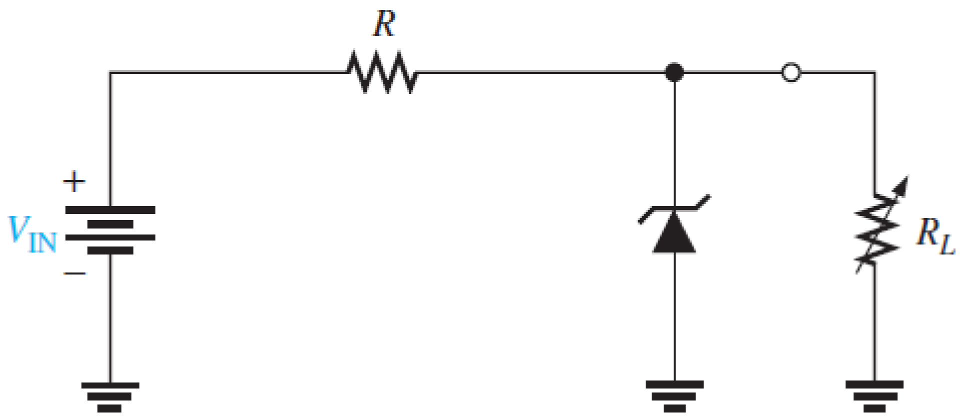


Zener Regulation with a Variable Load

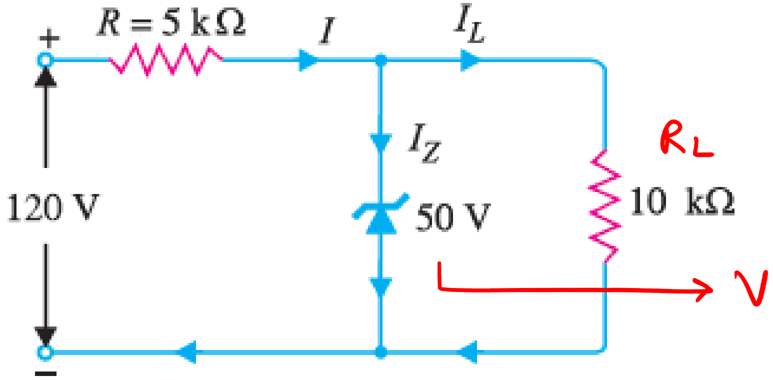
- The figure shows a zener voltage regulator with a variable load resistor across the terminals.
- The zener diode maintains a nearly constant voltage across as long as the zener current is greater than IZK and less than IZM.

From No Load to Full Load:

- When the output terminals of the zener regulator are open ($R_L = \infty$), the load current is zero and all the current is through the zener; this is a no-load condition. When a load resistor(R_L) is connected, part of the total current is through the zener and part through R_L.
- The total current through R remains essentially constant as long as the zener is regulating.
- As R_L is decreased, the load current I_L, increases and decreases I_Z.
- The zener diode continues to regulate the voltage until I_Z reache its minimum value I_{ZK}. At this point the load current is maximum, and a full-load condition exists.



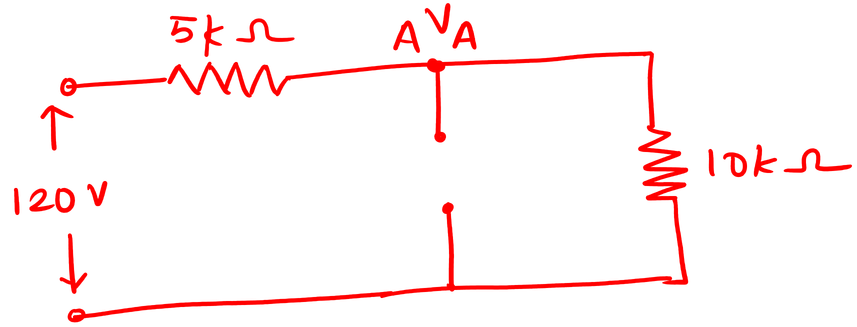
For the circuit shown in Fig. , find : (i) the output voltage (ii) the voltage drop across series resistance (iii) the current through zener diode.



$\to V_Z = 50V$

To check whether zener diode is ON,

$V_A \geq 50V$

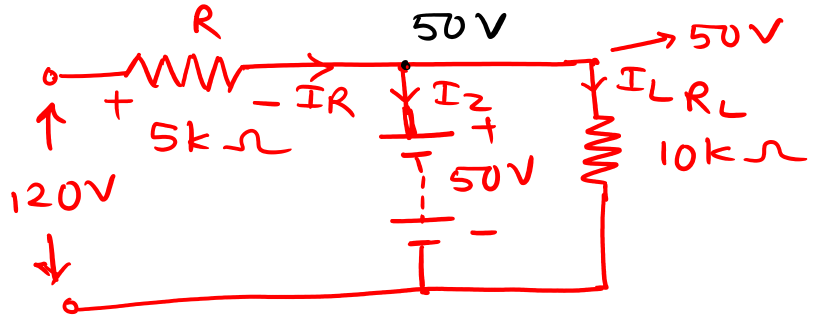


$$V_A = \left(\frac{10k}{5k+10k}\right) \cdot 120V$$

$$= 80V$$

As $V_A \geq 50V$

zener diode is ON.



i) the output voltage = 50V

ii) voltage drop across R = 120V − 50V

$\therefore V_R = 70V$

iii) current thr zener (I_Z) =

$I_R = I_Z + I_L \to I_L = I_R - I_Z$

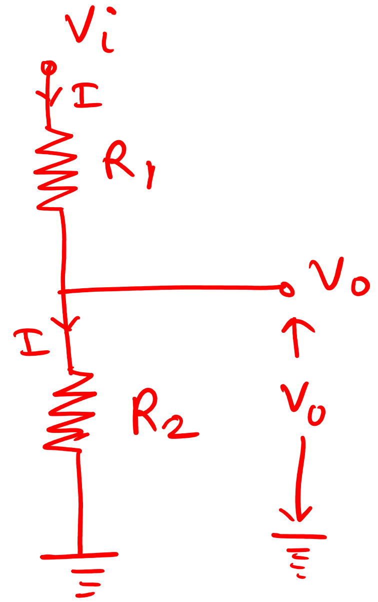
$\therefore I_Z = I_R - I_L$

$I_R = \frac{70V}{5k} = 14mA$ $\quad I_L = \frac{50V}{10k} = 5mA$

$I_Z = 14 - 5 = 9mA$

$\therefore I_Z = 9mA$

Voltage Divider Rule :



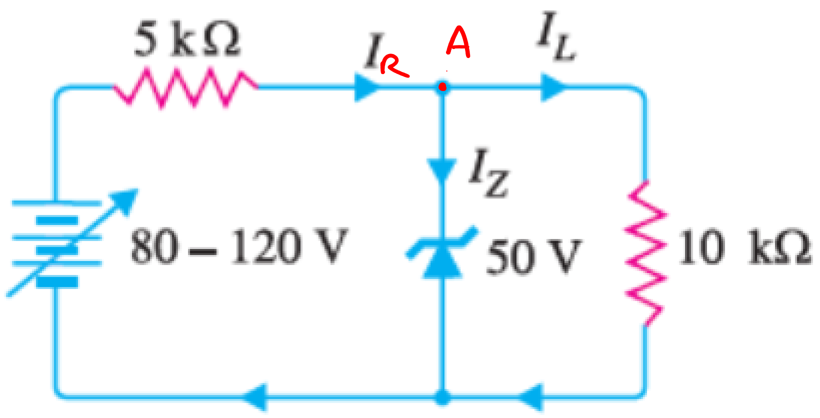
$$V_o = I \cdot R_2$$

$$I = \frac{V_i}{R_1 + R_2}$$

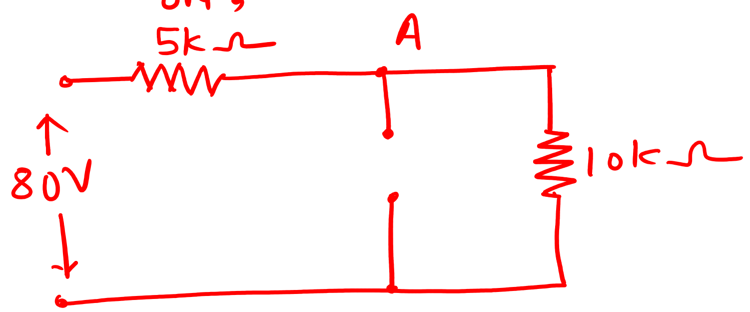
$$V_o = \left(\frac{V_i}{R_1 + R_2}\right) \cdot R_2$$

$$\therefore \quad V_o = \frac{R_2}{R_1 + R_2} \cdot V_i$$

For the circuit shown in Fig. 2, find the maximum and minimum values of zener diode current.



→ To check whether zener diode is ON,



$$V_A = \left(\frac{10k}{5k+10k}\right) \cdot 80V$$

$$= 53.33V$$

As $V_A > V_Z$,
zener diode is ON.

1) I_{ZK} : (At $V_i = 80V$)

$$I_{ZK} = I_R - I_L$$

$$\therefore I_R = \frac{80-50}{5k\Omega} = \frac{30}{5k\Omega} = 6mA \qquad I_L = \frac{50}{10k\Omega} = 5mA$$

$$\therefore I_{ZK} = 6mA - 5mA = 1mA$$

2) I_{ZM} : (At $V_i = 120V$)

$$I_{ZM} = I_R - I_L$$

$$I_R = \frac{120-50}{5k\Omega} = 14mA \qquad I_L = \frac{50}{10k\Omega} = 5mA$$

$$\therefore I_{ZM} = 14mA - 5mA = 9mA$$

Difference between Zener & PN Junction Diodes

S. No	P-n junction diode	Zener diode
1.	The electricity flows in one direction.	The electricity flows in both the direction.
2.	The reverse bias permanently damages the depletion region.	The reverse bias makes the electricity flow in both the direction.
3.	The width of depletion region is large because the p and n region is lightly doped.	The width of depletion region is narrow because the p and n region is heavily doped.
4.	This is used for rectification.	This is used for voltage regulation.

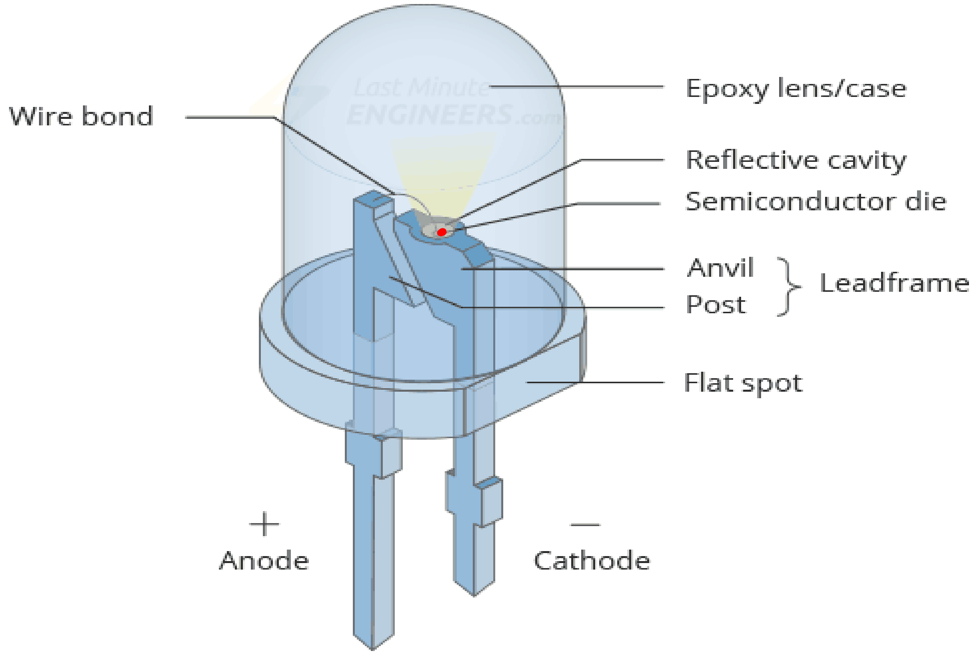
Difference between Avalanche and Zener breakdown

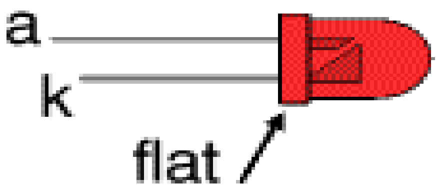
S. No.	Avalanche Breakdown	Zener Breakdown
1	The breakdown which occurs because of the collision of the electrons inside the PN-junction is called avalanche breakdown	The Zener breakdown occurs when the heavy electric field is applied across the PN-junction.
2	The avalanche breakdown occurs in the thick region	The Zener breakdown occurs in the thin region.
3	After the avalanche breakdown, the junction of the diode will not regain its original position	After the Zener breakdown the junction regains its original position.
4	The avalanche breakdown produces the pairs of electrons and holes because of the thermal effects	The Zener diode produces the electrons
5	The avalanche breakdown occurs in low doping material	The Zener breakdown occurs in high doping material.
6	The avalanche breakdown voltage causes because of high reverse potential because it is lightly doped	The Zener breakdown is because of low reverse potential.
7	The temperature coefficient of the avalanche breakdown is positive	The temperature coefficient of Zener breakdown is negative.
8	In avalanche breakdown, the mechanism of ionisation occurs because of collision of electrons	In the Zener breakdown ionisation occurs because of the electric field.
9	The avalanche breakdown voltage is directly proportional to the temperature	The Zener breakdown voltage is inversely proportional to the temperature.
10	The existence of the electric field is less on the avalanche breakdown	The existence of the electric field is more on the Zener breakdown

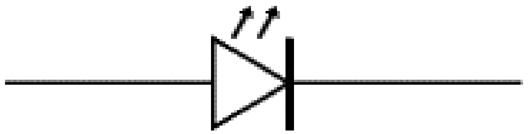
Light Emitting Diode

- A light emitting diode (LED) is essentially a PN junction opto-semiconductor that emits a monochromatic (single color) light when operated in a forward biased direction.

- LEDs convert electrical energy into light energy.







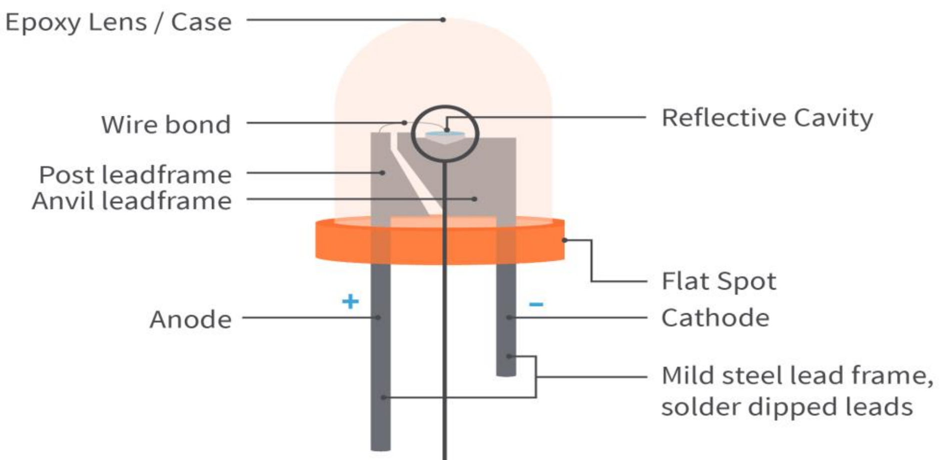
Light Emitting Diode(LED)

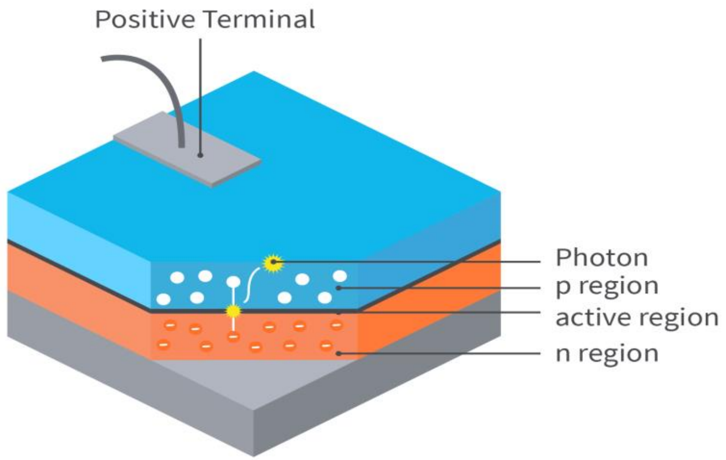
- Semiconductor diode: whenever an electron recombines with a hole, energy is released for a brief moment in the form of a photon.
- The photons produced are mostly converted to heat within the silicon in ordinary PN Diodes.
- Only a very small amount of light can escape the diode structure.
- This light also has a wavelength limited to the infrared region.

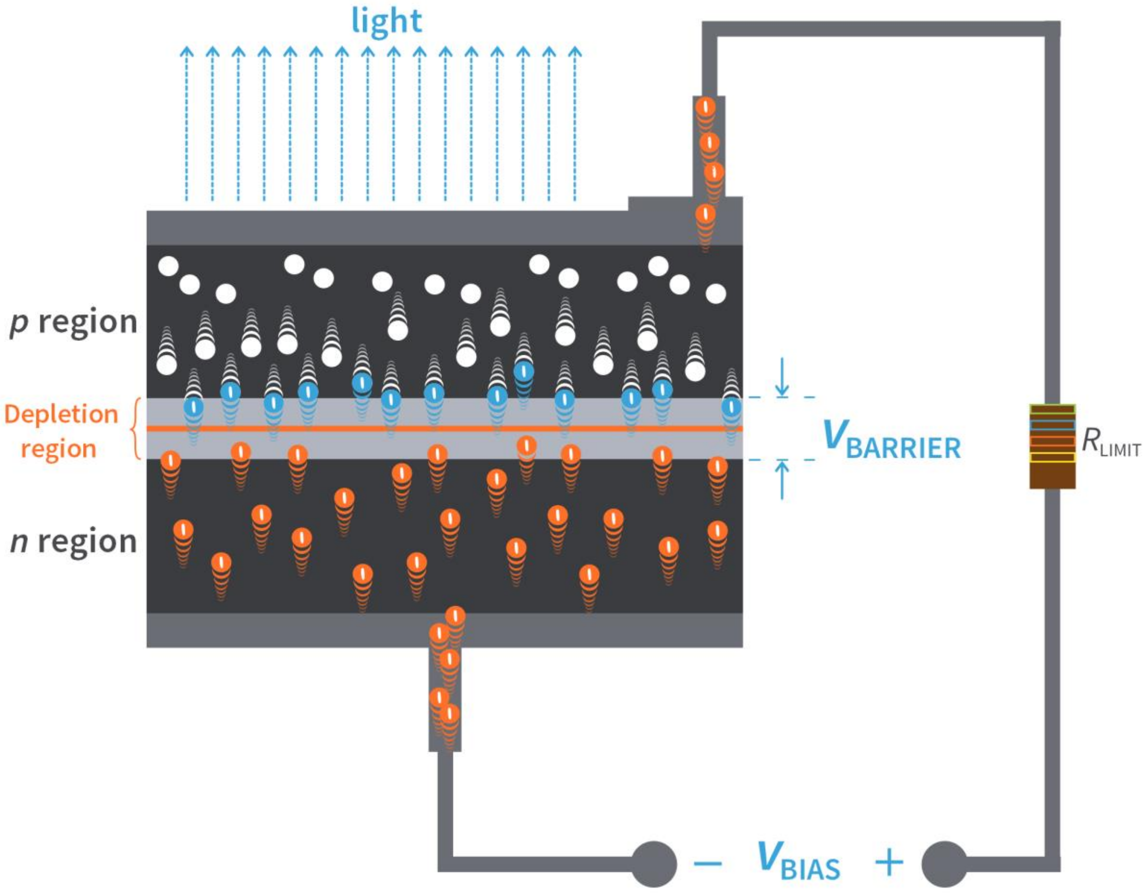
LEDs

- The most important part of a light emitting diode (LED) is the semi-conductor chip located in the center of the bulb.
- The chip has two regions separated by a junction.
- The junction acts as a barrier to the flow of electrons between the p and the n regions.

LED: Construction and Working







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How does A LED Work?

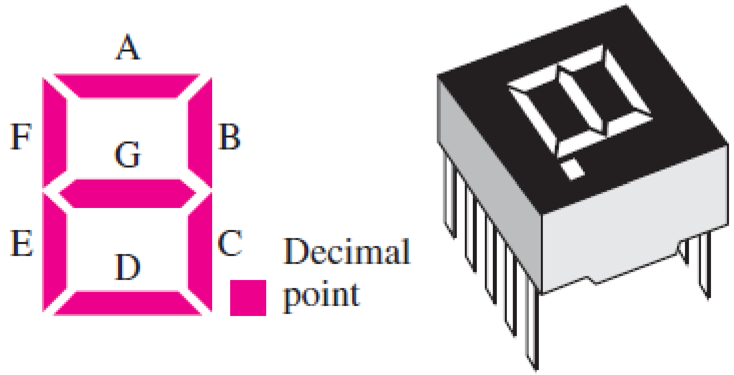
- When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the junction between the p and n regions.
- When a voltage is applied and the current starts to flow, electrons in the n region have sufficient energy to move across the junction into the p region.
- 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.

How much Energy does an LED emit?

- 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.
- The constant q is the electric charge of a single electron.

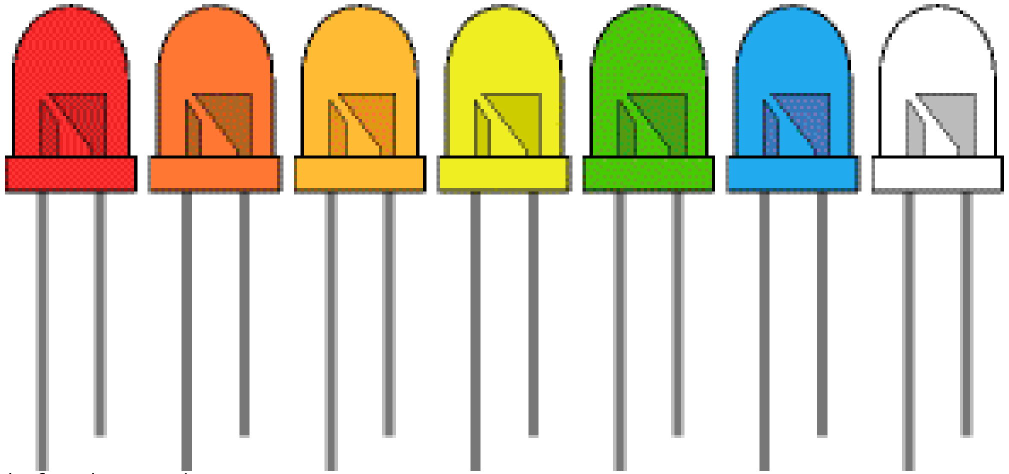
Applications

- Sensor Applications
- Mobile Applications
- LED Signals
- Illuminations
- Indicators



Colors of LEDs

- LEDs are made from gallium-based crystals that contain one or more additional materials such as phosphorous to produce a distinct color.
- Different LED chip technologies emit light in specific regions of the visible light spectrum and produce different intensity levels.
- LEDs are available in red, orange, amber, yellow, green, blue and white.

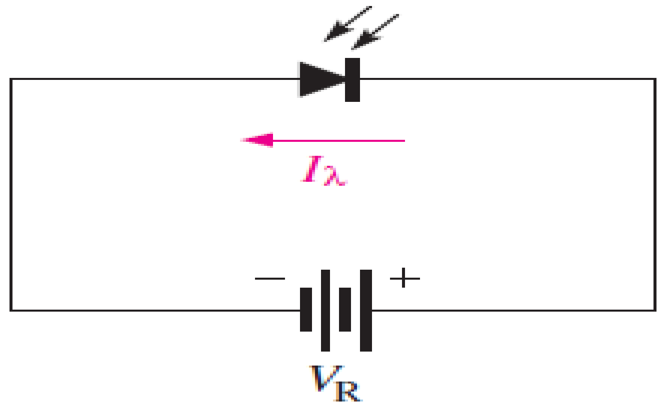


CircuitBread | LED COLORS AND MATERIALS

Color	Wavelength Range (nm)	Forward Voltage (V)	Material
Ultraviolet	< 400	3.1 - 4.4	Aluminium nitride (AlN) Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN)
Violet	400 - 450	2.8 - 4.0	Indium gallium nitride (InGaN)
Blue	450 - 500	2.5 - 3.7	Indium gallium nitride (InGaN) Silicon carbide (SiC)
Green	500 - 570	1.9 - 4.0	Gallium phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP)
Yellow	570 - 590	2.1 - 2.2	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium phosphide (GaP)
Orange / Amber	590 - 610	2.0 - 2.1	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaUInP) Gallium phosphide (GaP)
Red	610 - 760	1.6 - 2.0	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium phosphide (GaP)
Infrared	> 760	> 1.9	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)

Photodiode

- A photodiode is a PN-junction diode that consumes light energy to produce electric current.
- It is also called as photo-detector, a light detector, and photo-sensor.
- These diodes are particularly designed to work in reverse bias condition, it means that the P-side of the photodiode is associated with the negative terminal of the battery and n-side is connected to the positive terminal of the battery.

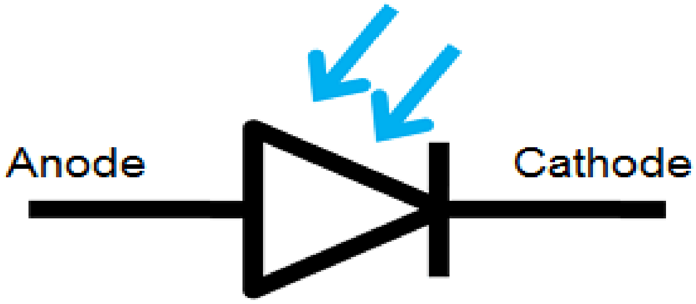


(a) Reverse-bias operation using standard symbol

Photo Diode

- Photodiodes basically perform the opposite effect to LEDs and laser diodes.
- Instead of using electric current to cause electrons and holes to combine to create photons, photodiodes absorb light energy (photons) to generate electron/hole pairs, so creating an electric current flow.
- Two basic methods for generating electricity from light,
  - Photovoltaic
  - Photoconductive

Symbol



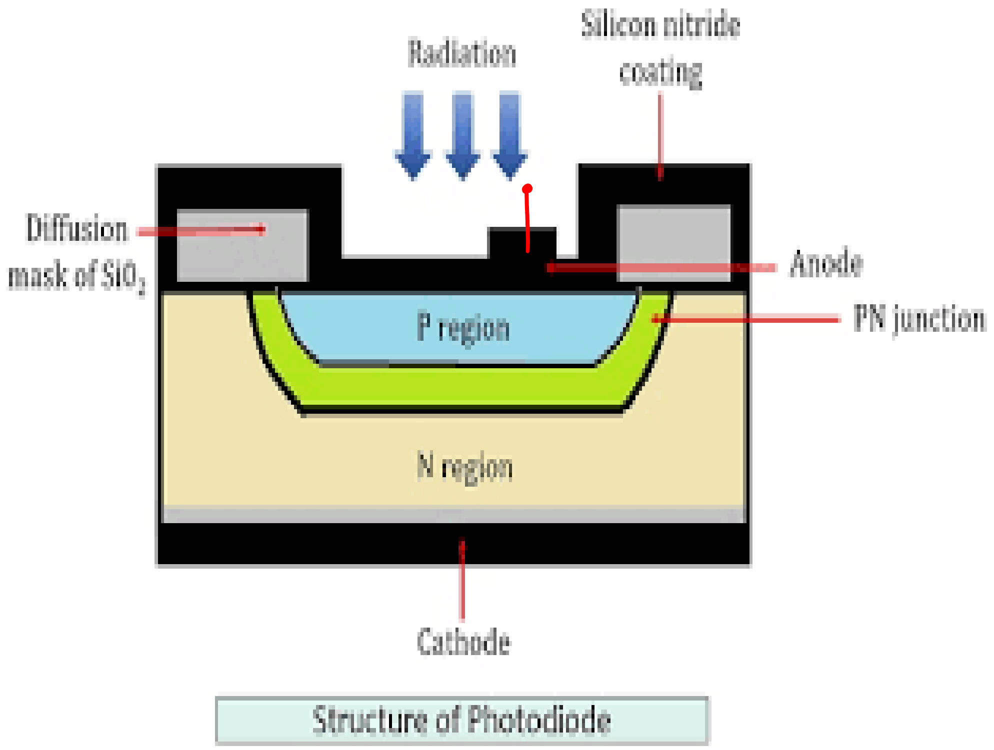
Photodiode symbol

- Under forward bias condition, conventional current will flow from the anode to the cathode.
- Photocurrent flows in the reverse direction.

Working of Photodiode

- The working principle of a photodiode is, when a photon of ample energy strikes the diode, it makes a couple of an electron-hole.
- This mechanism is also called as the inner photoelectric effect.
- A photodiode differs from a rectifier diode in that when its pn junction is exposed to light, the reverse current increases with the light intensity.
- When there is no incident light, the reverse current, is almost negligible and is called the dark current. An increase in the amount of light intensity, expressed as irradiance (mW/cm2), produces an increase in the reverse current.

Working of Photodiode



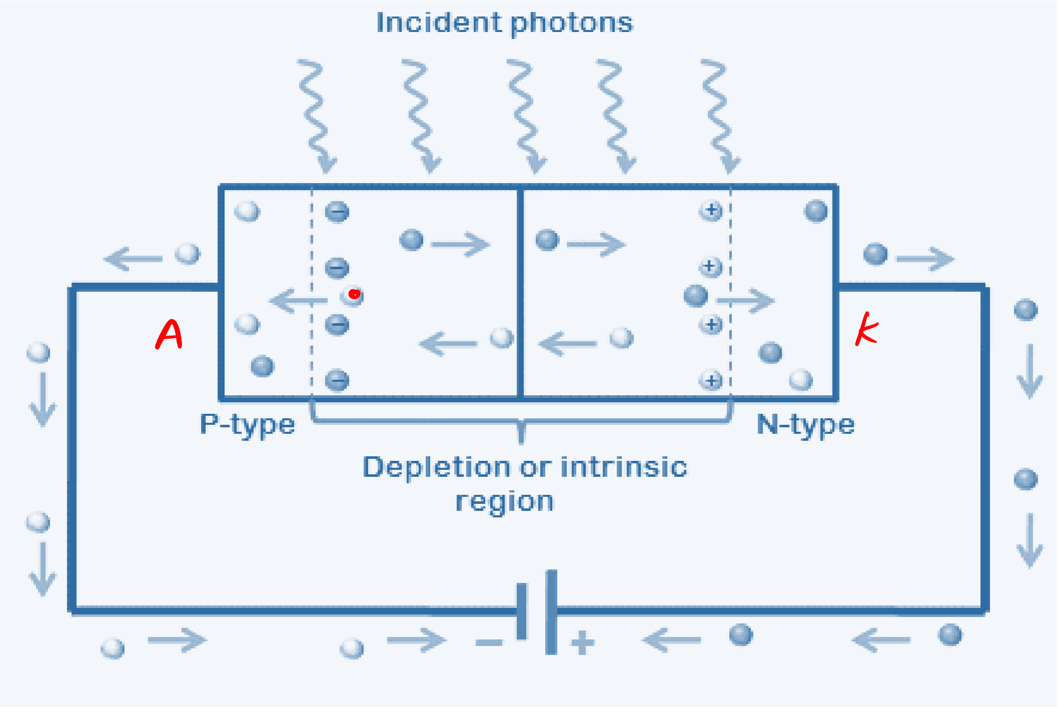
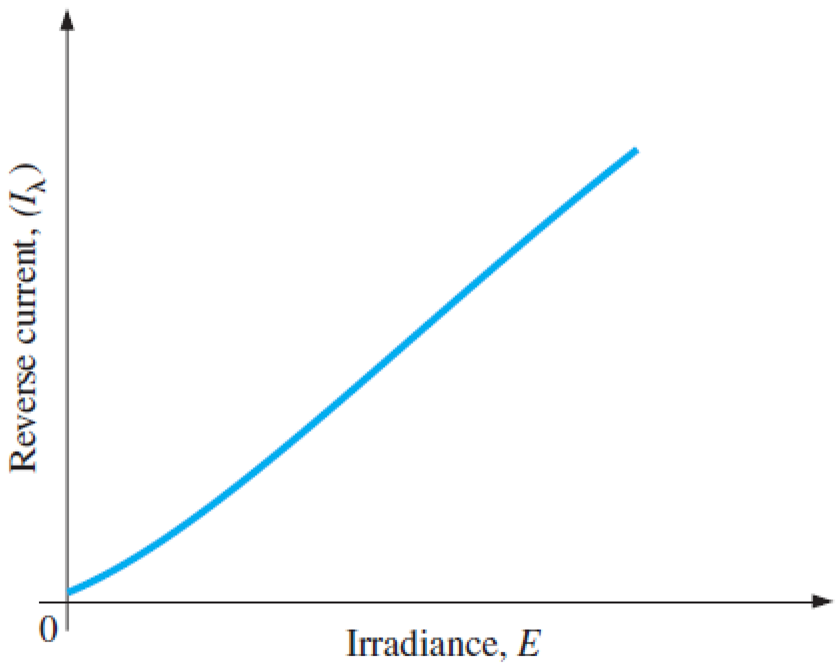
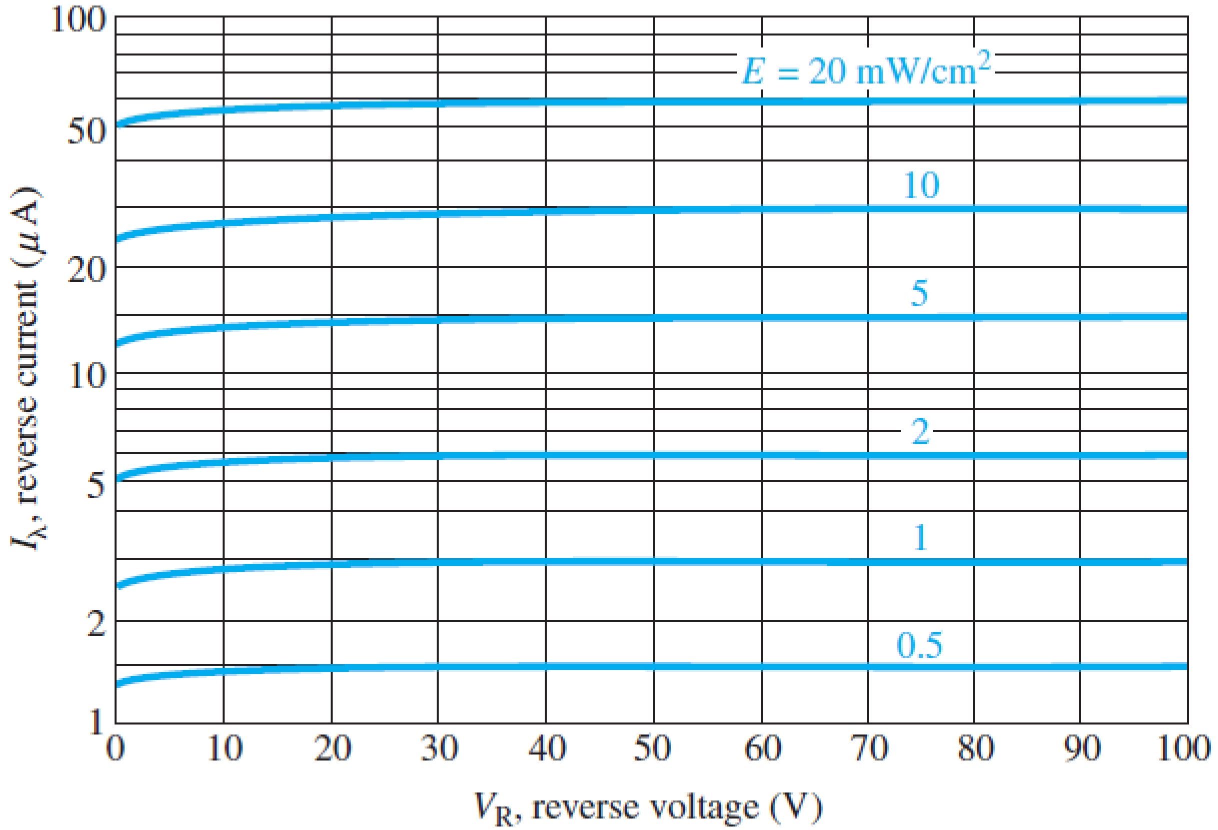


Photo Diode Characteristics



(a) General graph of reverse current versus irradiance



(b) Example of a graph of reverse current versus reverse voltage for several values of irradiance

Key Points

- Diodes allow current to flow in only one direction.
- At low temperatures, semiconductors act like insulators.
- At higher temperatures, they begin to conduct.
- Doping of semiconductors leads to the production of *p*-type and *n*-type materials
- A junction between *p*-type and *n*-type semiconductors has the properties of a diode
- Silicon semiconductor diodes approximate the behavior of ideal diodes but have a conduction voltage of about 0.7 V
- There are also a wide range of special purpose diodes
- Diodes are used in a range of applications

Acknowledgements

1. Electronic Devices, Thomas L. Floyd
2. Web Resources

Thank You..