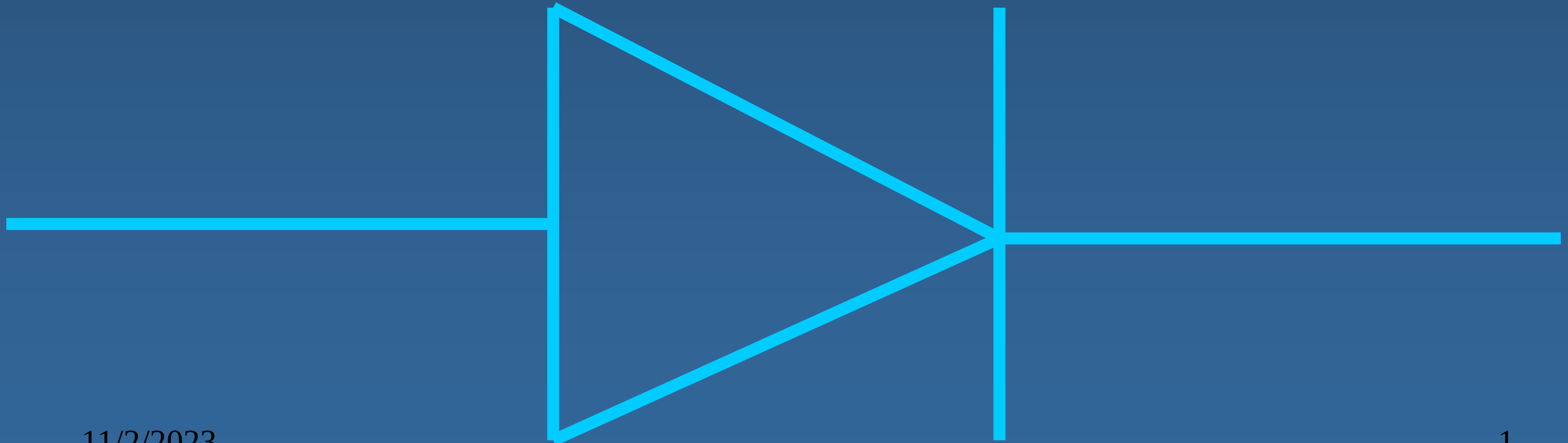
P. N. JUNCTION DIODES

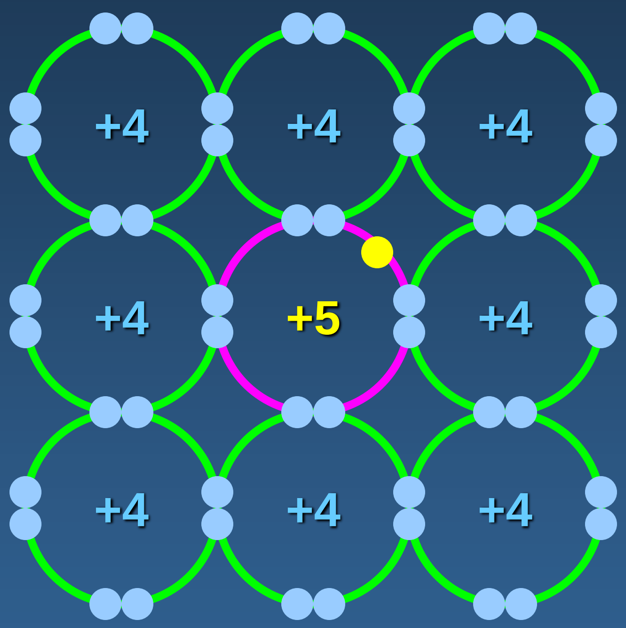
Presented By

Assist. Prof. Mr. A. N. Gore



N-Type Material

N-Type Material:

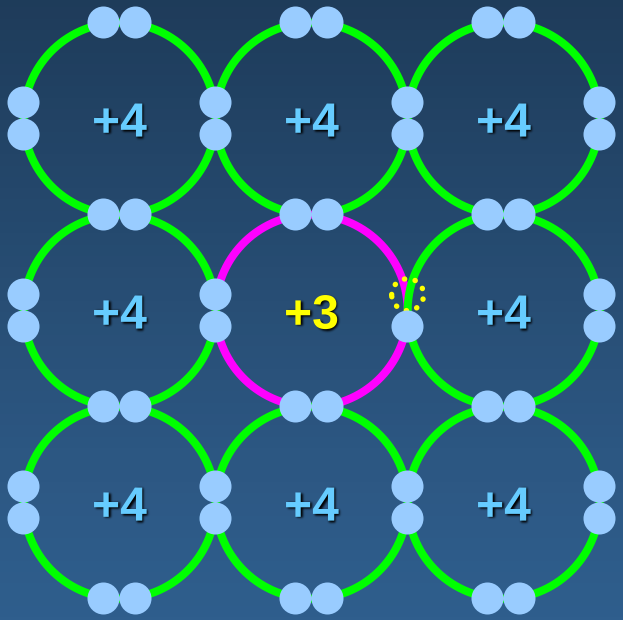


When extra valence electrons are introduced into a material such as silicon an n-type material is produced. The extra valence electrons are introduced by putting impurities or dopant into the silicon. The dopant used to create an n-type material are Group V elements. The most commonly used dopant from Group V are arsenic, antimony and phosphorus.

The 2D diagram to the left shows the extra electron that will be present when a Group V dopant is introduced to a material such as silicon. This extra electron is very mobile.

P-Type Material

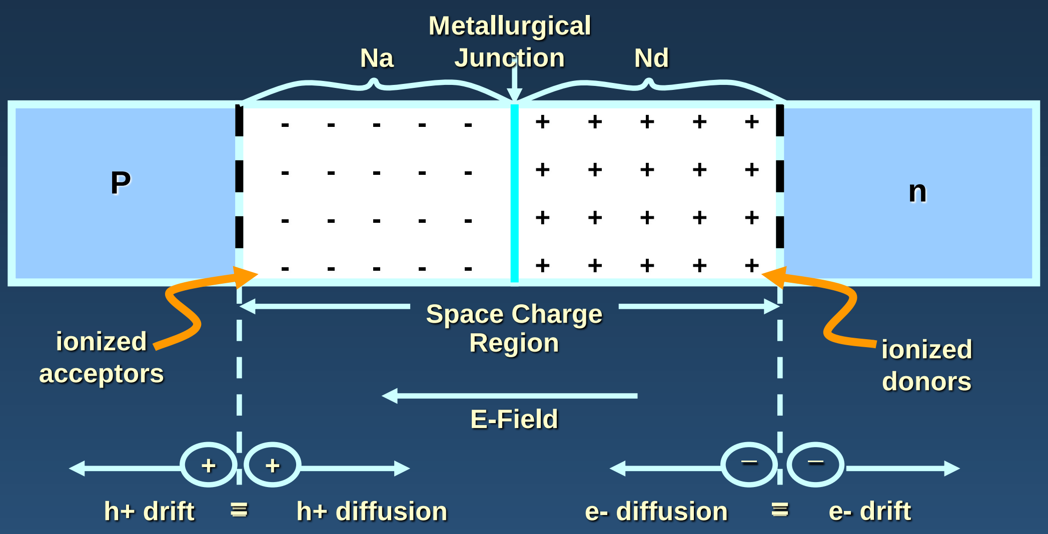
P-Type Material:



P-type material is produced when the dopant that is introduced is from Group III. Group III elements have only 3 valence electrons and therefore there is an electron missing. This creates a hole (h+), or a positive charge that can move around in the material. Commonly used Group III dopant are aluminum, boron, and gallium.

The 2D diagram to the left shows the hole that will be present when a Group III dopant is introduced to a material such as silicon. This hole is quite mobile in the same way the extra electron is mobile in a n-type material.

The PN Junction



Steady State

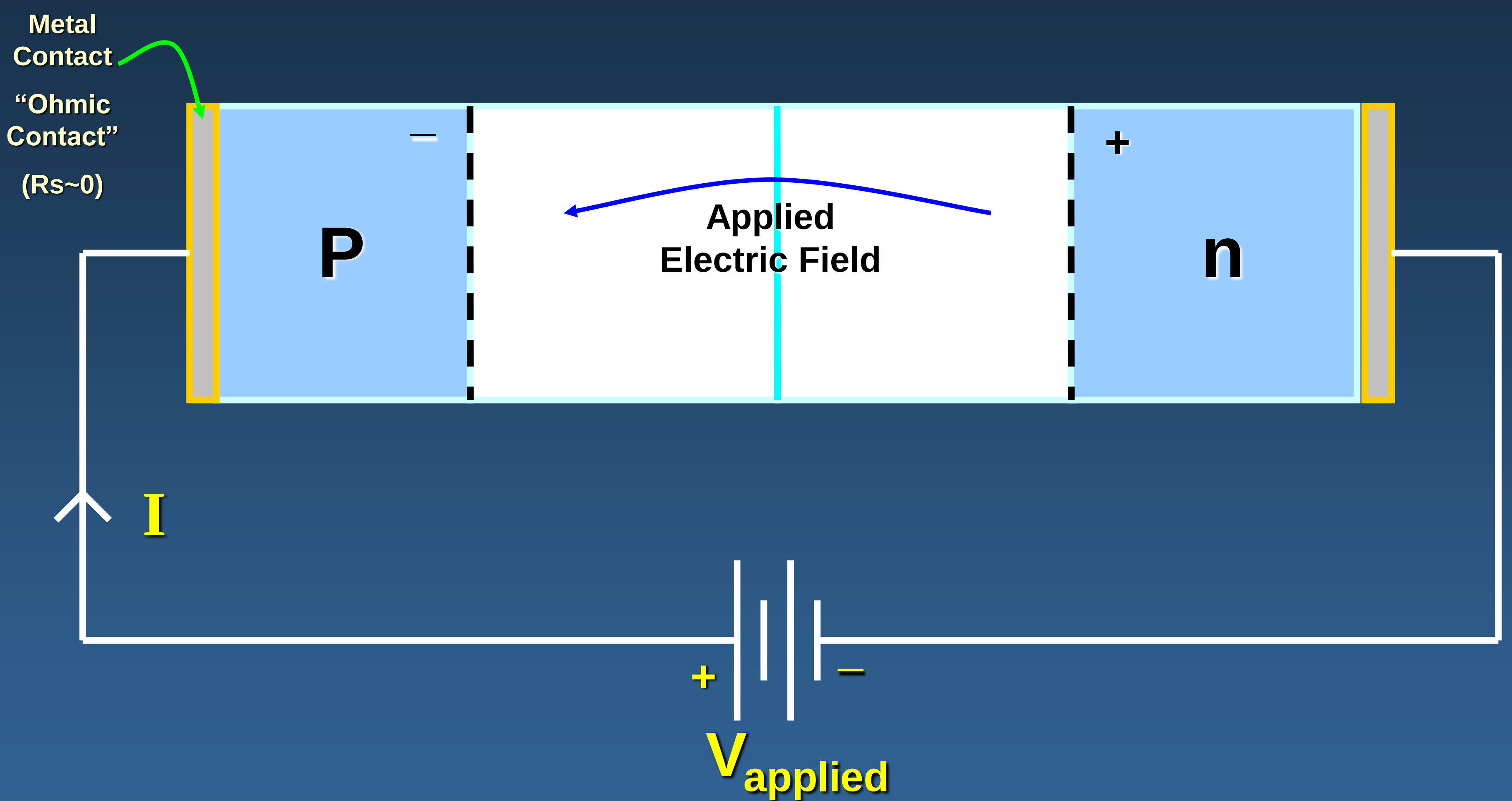
When no external source is connected to the pn junction, diffusion and drift balance each other out for both the holes and electrons

Space Charge Region: Also called the depletion region. This region includes the net positively and negatively charged regions. The space charge region does not have any free carriers. The width of the space charge region is denoted by W in pn junction formula's.

Metallurgical Junction: The interface where the p- and n-type materials meet.

Na & Nd: Represent the amount of negative and positive doping in number of carriers per centimeter cubed. Usually in the range of 10^{15} to 10^{20}.

The Biased PN Junction



The pn junction is considered biased when an external voltage is applied. There are two types of biasing: Forward bias and Reverse bias. These are described on then next slide.

The Biased PN Junction

Forward Bias:

$V_{applied} > 0$

In forward bias the depletion region shrinks slightly in width. With this shrinking the energy required for charge carriers to cross the depletion region decreases exponentially. Therefore, as the applied voltage increases, current starts to flow across the junction. The barrier potential of the diode is the voltage at which appreciable current starts to flow through the diode. The barrier potential varies for different materials.

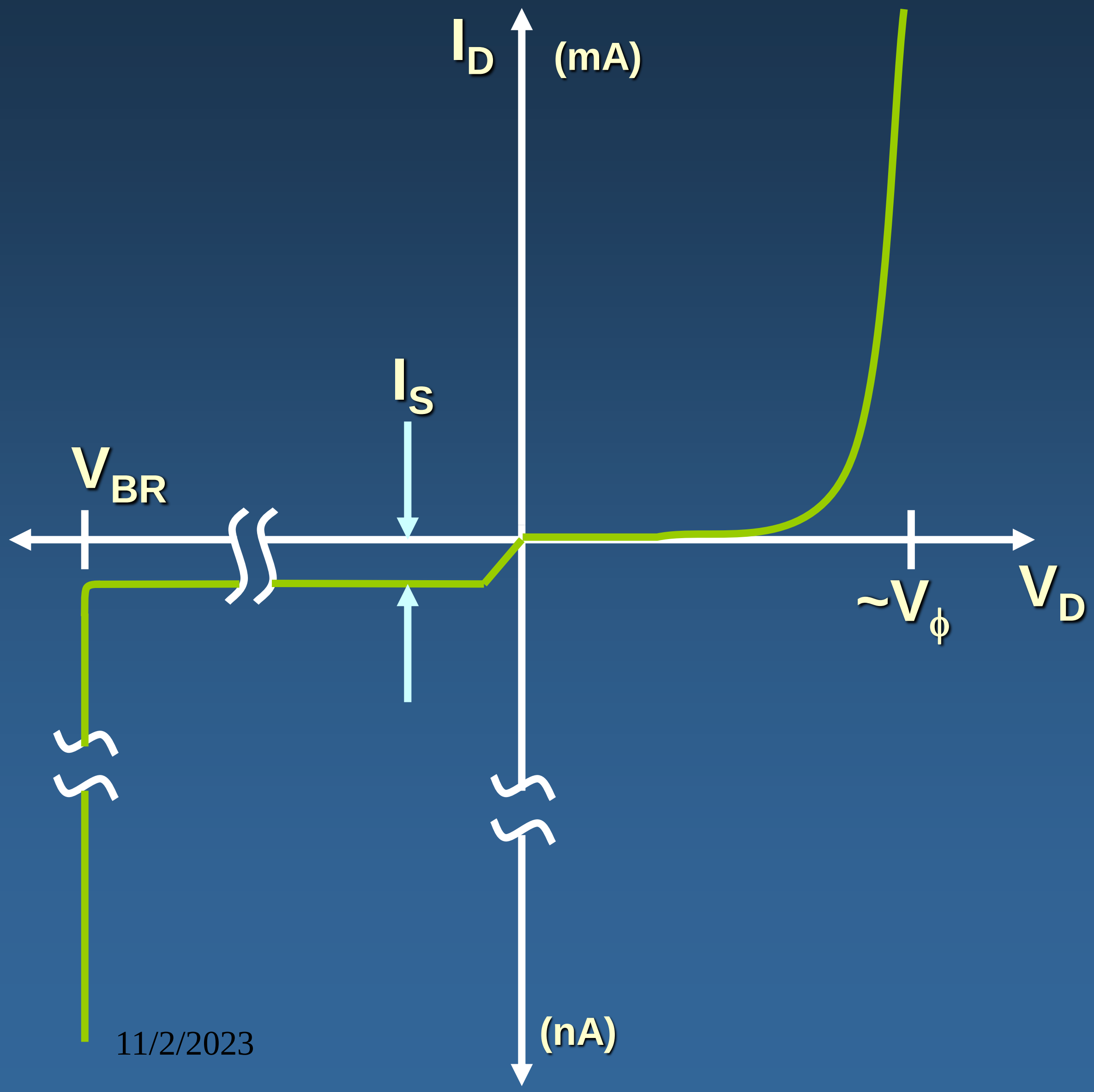
Reverse Bias:

$V_{applied} < 0$

Under reverse bias the depletion region widens. This causes the electric field produced by the ions to cancel out the applied reverse bias voltage. A small leakage current, Is (saturation current) flows under reverse bias conditions. This saturation current is made up of electron-hole pairs being produced in the depletion region. Saturation current is sometimes referred to as scale current because of it's relationship to junction temperature.

Properties of Diodes

Figure 1.10 – The Diode Transconductance Curve[2]



- V_D = Bias Voltage
- I_D = Current through Diode. I_D is Negative for Reverse Bias and Positive for Forward Bias
- I_S = Saturation Current
- V_{BR} = Breakdown Voltage
- V_ϕ = Barrier Potential Voltage

Properties of Diodes

The Shockley Equation

- The transconductance curve on the previous slide is characterized by the following equation:

$$I_D = I_S(e^{V_D/\eta V_T} - 1)$$

- As described in the last slide, I_D is the current through the diode, I_S is the saturation current and V_D is the applied biasing voltage.
- V_T is the thermal equivalent voltage and is approximately 26 mV at room temperature. The equation to find V_T at various temperatures is:

$$V_T = \frac{kT}{q}$$

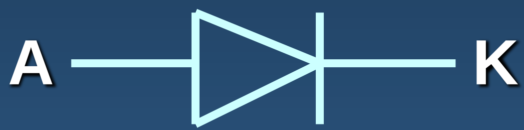
$k = 1.38 \times 10^{-23}$ J/K   T = temperature in Kelvin $q = 1.6 \times 10^{-19}$ C

- η is the emission coefficient for the diode. It is determined by the way the diode is constructed. It somewhat varies with diode current. For a silicon diode η is around 2 for low currents and goes down to about 1 at higher currents

Types of Diodes and Their Uses

PN Junction Diodes:

Are used to allow current to flow in one direction while blocking current flow in the opposite direction. The pn junction diode is the typical diode that has been used in the previous circuits.

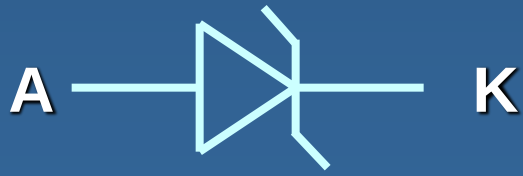


Schematic Symbol for a PN Junction Diode

Representative Structure for a PN Junction Diode

Zener Diodes:

Are specifically designed to operate under reverse breakdown conditions. These diodes have a very accurate and specific reverse breakdown voltage.

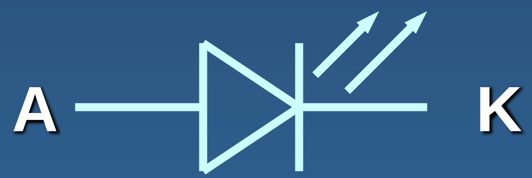


Schematic Symbol for a Zener Diode

Types of Diodes and Their Uses

Light-Emitting Diodes:

Light-emitting diodes are designed with a very large band gap so movement of carriers across their depletion region emits photons of light energy. Lower band gap LEDs (Light-Emitting Diodes) emit infrared radiation, while LEDs with higher band gap energy emit visible light. Many stop lights are now starting to use LEDs because they are extremely bright and last longer than regular bulbs for a relatively low cost.

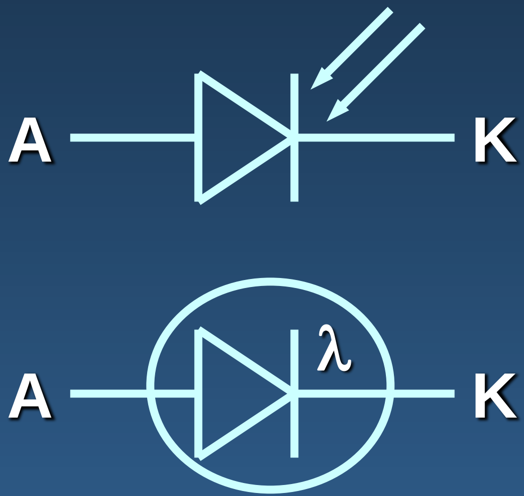


Schematic Symbol for a Light-Emitting Diode

The arrows in the LED representation indicate emitted light.

Types of Diodes and Their Uses

Photodiodes:



Schematic Symbols for Photodiodes

While LEDs emit light, Photodiodes are sensitive to received light. They are constructed so their pn junction can be exposed to the outside through a clear window or lens.

In Photoconductive mode the saturation current increases in proportion to the intensity of the received light. This type of diode is used in CD players.

In Photovoltaic mode, when the pn junction is exposed to a certain wavelength of light, the diode generates voltage and can be used as an energy source. This type of diode is used in the production of solar power.

THANK YOU