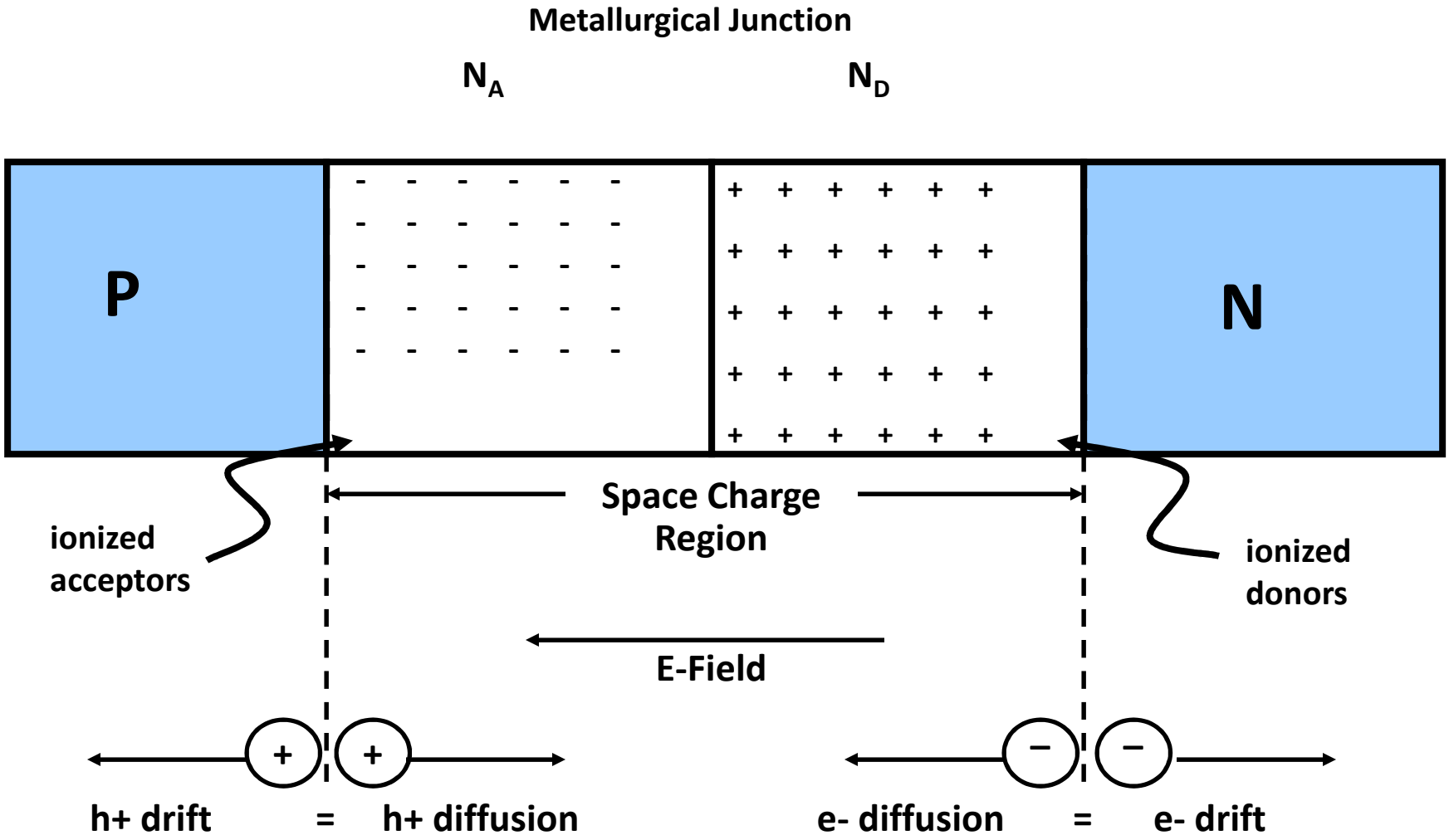
Faculty of Engineering

ECE 335: Electronic Engineering

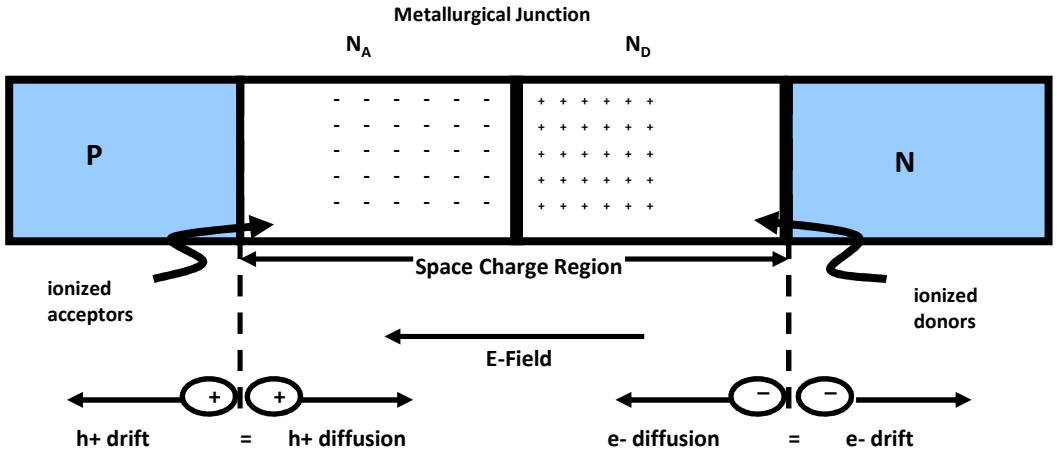
Lecture 5:
PN Junction (Diode)

The PN Junction

Steady State[1]



The PN Junction

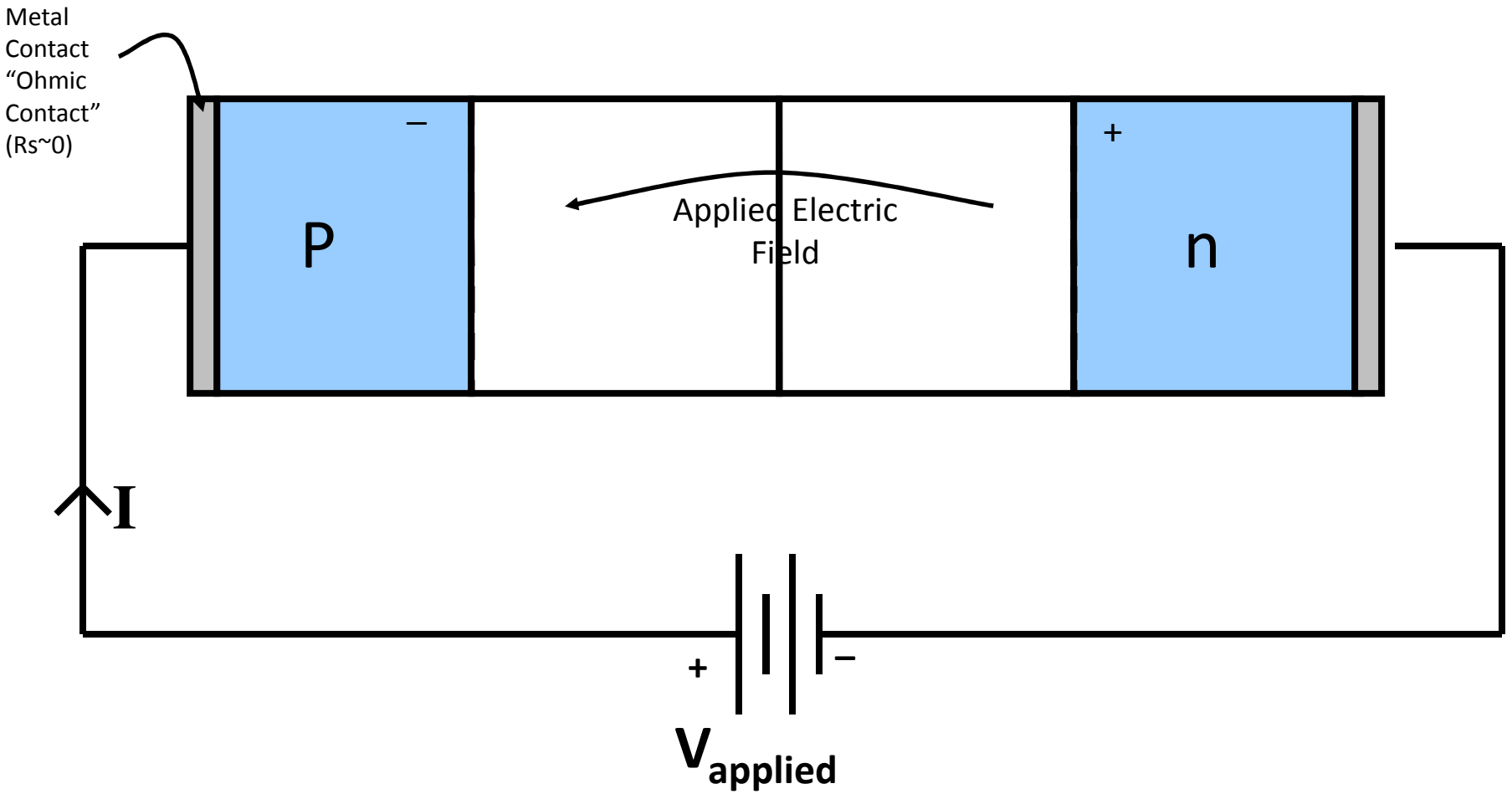


At steady state, when no external source is connected to the pn junction, diffusion and drift balance each other out for both the holes and electrons

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 formulae.

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

The Biased PN Junction



The pn junction is considered biased when an external voltage is applied.

The Biased PN Junction

Forward Bias:

$V_{applied} > 0$

- Depletion region shrinks slightly in width.
- Energy required for charge carriers to cross the depletion region decreases exponentially.
- 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.

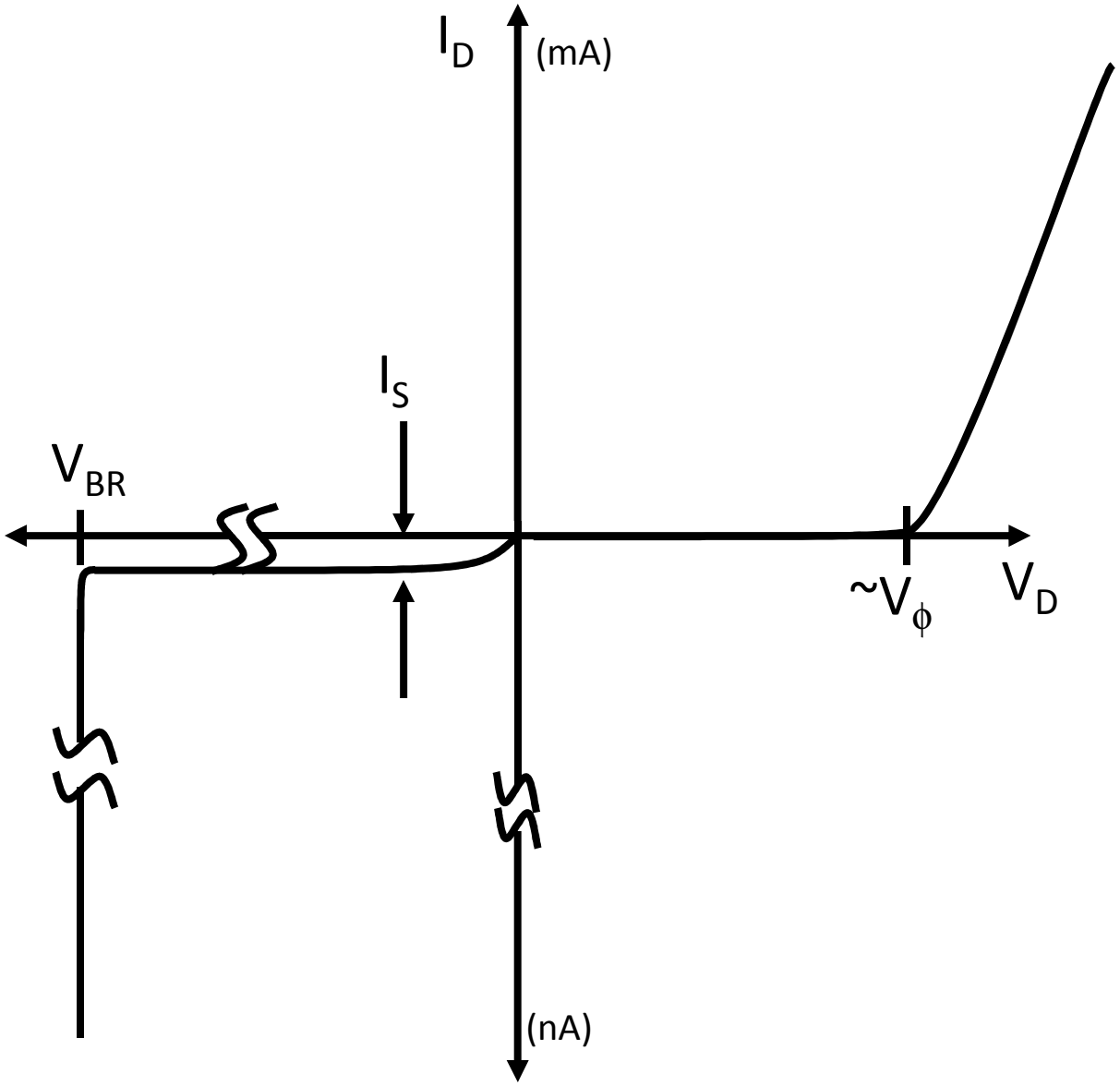
Reverse Bias:

$V_{applied} < 0$

Depletion region widens.
A small leakage current, I_s (saturation current) flows under reverse bias conditions.
This saturation current is made up of electron-hole pairs being produced in the depletion region.

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

Diode I-V (Shockley) 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.

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

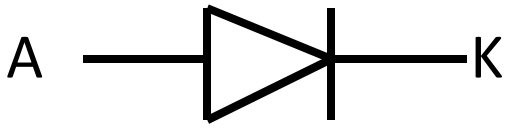
k = 1.38 x 10^{-23} J/K **T** = temperature in Kelvin **q** = 1.6 x 10^{-19} C

- 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.

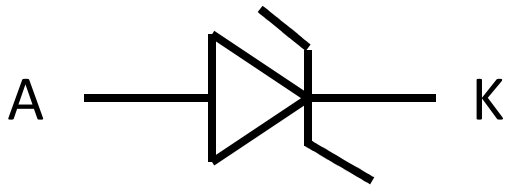


Schematic Symbol for a PN Junction Diode

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.

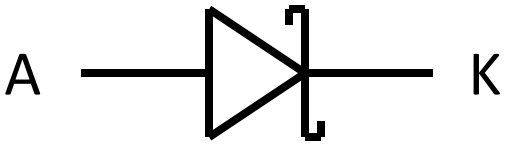


Schematic Symbol for a Zener Diode

Types of Diodes and Their Uses

Schottky Diodes:

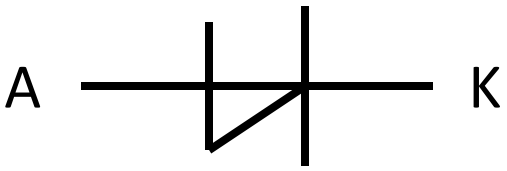
These diodes are designed to have a very fast switching time which makes them a great diode for digital circuit applications. They are very common in computers because of their ability to be switched on and off so quickly.



Schematic Symbol for a Schottky Diode

Shockley Diodes:

The Shockley diode is a four-layer diode while other diodes are normally made with only two layers. These types of diodes are generally used to control the average power delivered to a load.

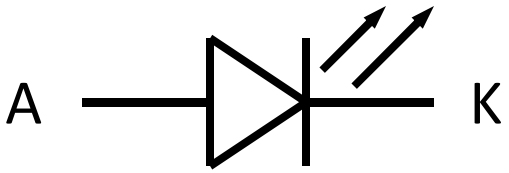


Schematic Symbol for a four-layer Shockley Diode

Types of Diodes and Their Uses

Light-Emitting Diodes (LED):

- Light-emitting diodes are designed with a very large bandgap so movement of carriers across their depletion region emits photons of light energy.
- Lower bandgap LEDs (Light-Emitting Diodes) emit infrared radiation, while LEDs with higher bandgap 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.

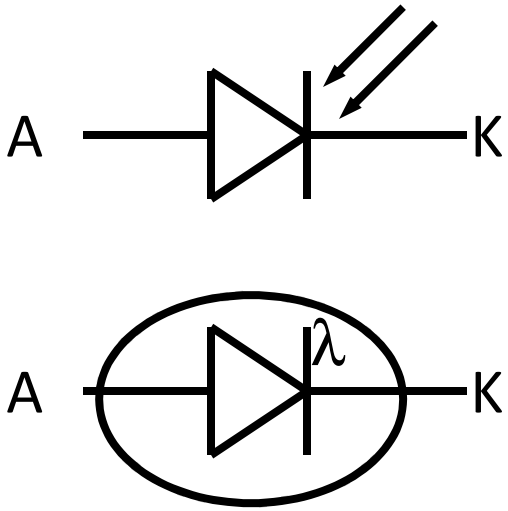


Schematic Symbol for a Light-Emitting Diode

The arrows in the LED representation indicate emitted light.

Types of Diodes and Their Uses

Photodiodes:



- 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.