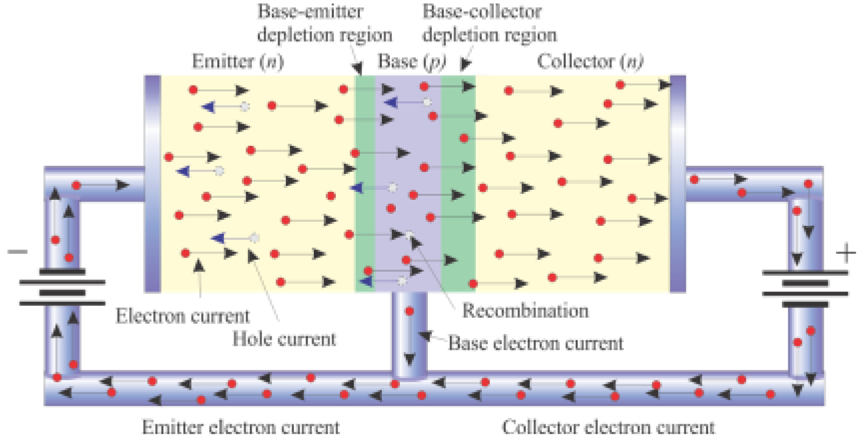
Electronic Devices

Ninth Edition

Floyd

Chapter 3



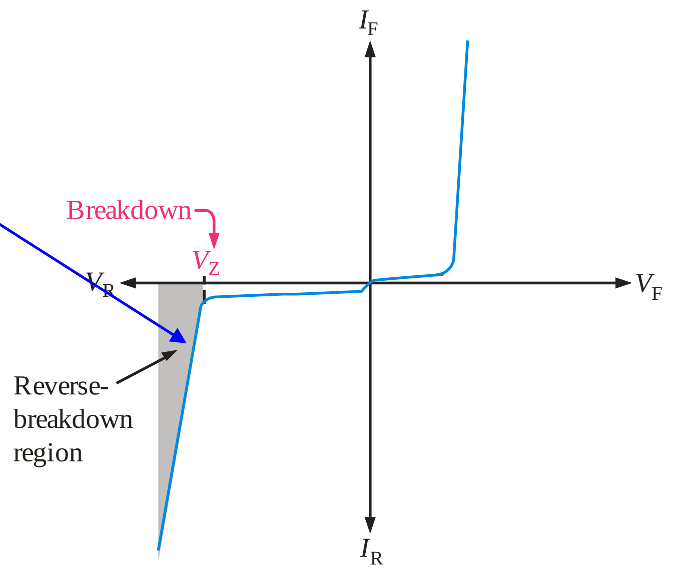
Summary

The Zener Diode

The zener diode is designed to operate in the reverse breakdown region.

Symbol

Ideally, the reverse breakdown has a constant breakdown voltage. This makes it useful as a voltage reference, which is its primary application.



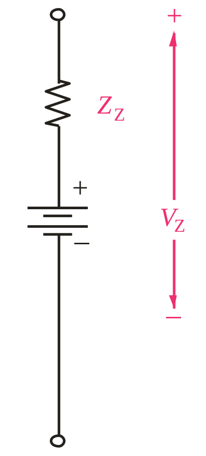
Characteristic curve

Summary

The Zener Diode

The zener impedance, Z_Z, is the ratio of a change in voltage in the breakdown region to the corresponding change in current:

$$Z_Z = \frac{\Delta V_Z}{\Delta I_Z}$$



Practical model

Example:

What is the zener impedance if the zener diode voltage changes from 4.79 V to 4.94 V when the current changes from 5.00 mA to 10.0 mA?

Solution:

$$Z_Z = \frac{\Delta V_Z}{\Delta I_Z} = \frac{0.15\text{ V}}{5.0\text{ mA}} = 30\ \Omega$$

Summary

The Zener Diode

The temperature coefficient of a zener diode can be specified as the percent change in zener voltage for each degree Celsius change in temperature:

$$TC = \left(\frac{\Delta V_Z}{V_Z}\right)\Delta T$$

where TC has units of %/°C.

Alternatively, it can be specified in terms of change in voltage per degree Celsius change in temperature.

$$TC = \frac{\Delta V_Z}{\Delta T}$$

where TC has units of mV/°C.

The Zener Diode

The temperature coefficient can be positive or negative, depending on the zener voltage. Above 5.6 V, zeners generally have a positive temperature coefficient; below about 5.6 V, they have a negative temperature coefficient.

Example:

A 1N756 is an 8.2 V zener diode (8.2 V at 25^{o} C) with a positive temperature coefficient of 5.4 mV/^{o}C. What is the output voltage if the temperature rises to 50^{o} C?

Solution:

$$\Delta V_Z = TC \times \Delta T = (5.4\ \text{mV})(25^{o}\ \text{C}) = 189\ \text{mV}$$

$$V_Z = 8.2\ \text{V} + 0.189\ \text{V} = 8.389\ \text{V}$$

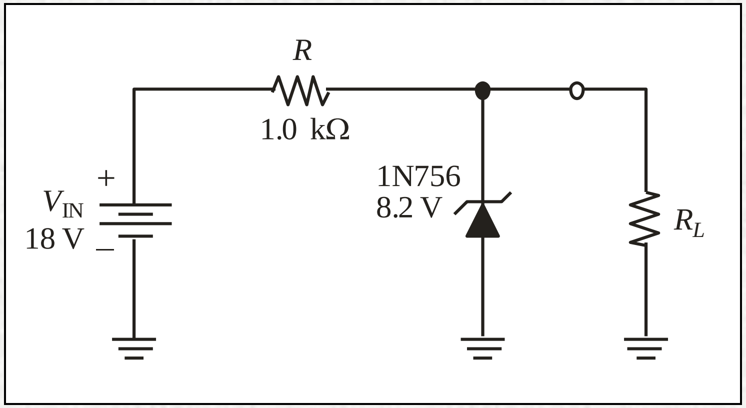
Summary

Zener Diode Applications

In low current applications, a zener diode can be used as a basic regulator.

Example:

A 1N756 (8.2 V at 25° C) is used as an 8.2 V regulator in the circuit shown. What is the smallest load resistor that can be used before losing regulation? Assume an ideal zener diode model.



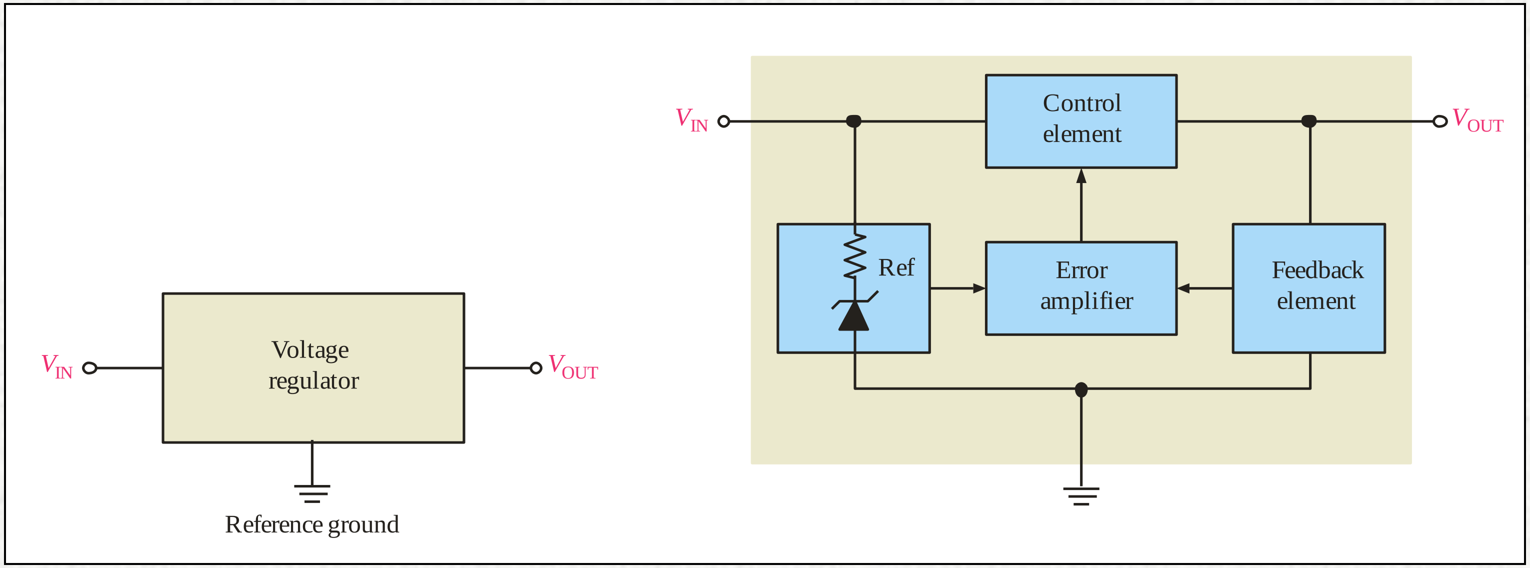
Solution:

The no load zener current is $I_{NL} = \dfrac{V_{IN} - V_Z}{R} = \dfrac{18\text{ V} - 8.2\text{ V}}{1.0\text{ k}\Omega} = 9.8\text{ mA}$

This is the maximum load current in regulation. Therefore, $R_L = \dfrac{8.2\text{ V}}{9.8\text{ mA}} = 837\ \Omega$

Zener Diode Applications

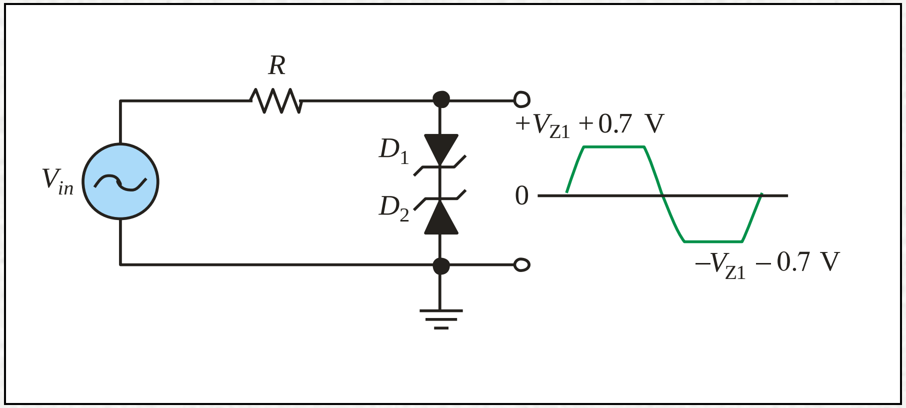
Zeners are used in three-terminal regulators to establish a reference voltage. These circuits are capable of much larger load currents than basic zener regulators.



Summary

Zener Diode Applications

Zeners can also be used as limiters. The back-to-back zeners in this circuit limit the output to the breakdown voltage plus one diode drop.



Question:

What are the maximum positive and negative voltages if the zener breakdown voltage is 5.6 V?

± 6.3 V

Summary

Varactor Diodes

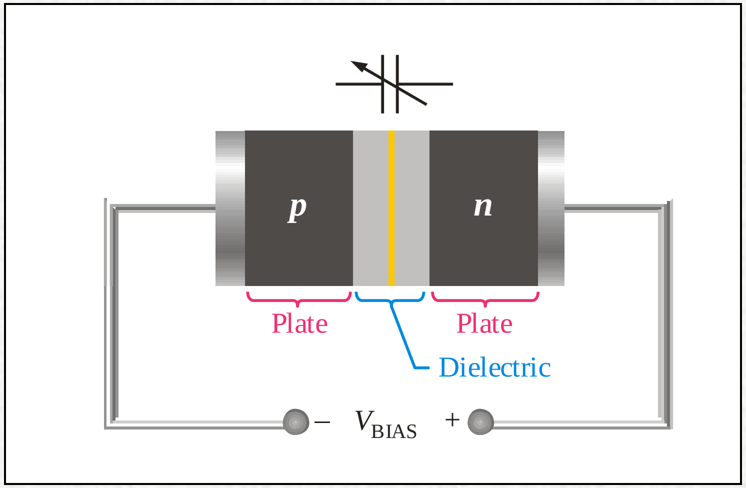
A varactor diode is a special purpose diode operated in reverse-bias to form a voltage-controlled capacitor. The width of the depletion region increases with reverse-bias.

Question:

If the depletion widens, does the capacitance increase or decrease?

Hint: $C = \frac{A\varepsilon}{d}$

Notice that as the effective plate separation widens, the capacitance will decrease.

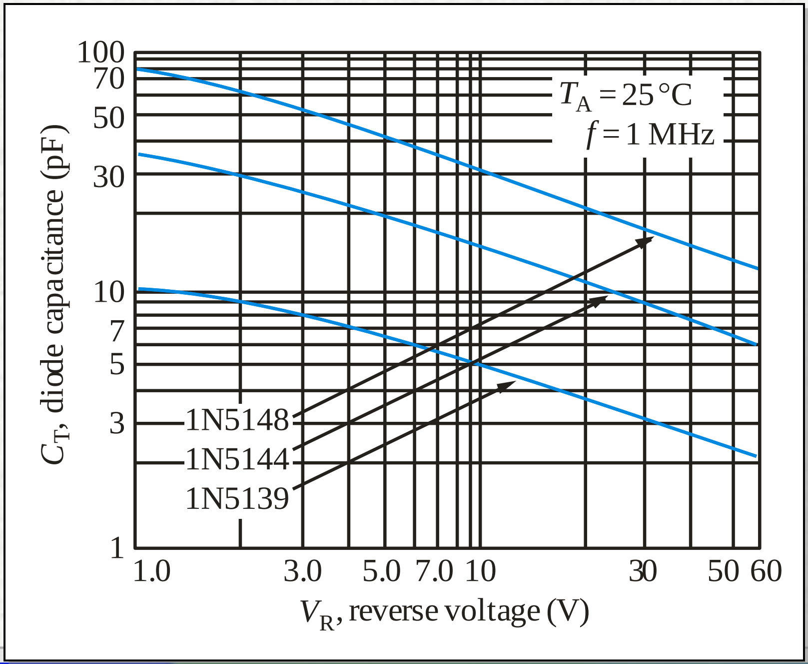


Summary

Varactor Diodes

Capacitance tolerance range are the range of values of capacitance for a given varactor. The data sheet will show the minimum nominal and maximum values, which are often plotted on a graph.

For example, you can use this graph to read the capacitance as a function of reverse voltage for various diodes.



Summary

Varactor Diodes

The **capacitance ratio** is the ratio of the diode's capacitance at the minimum reverse voltage (largest *C*) to the diode's capacitance at the maximum reverse voltage (smallest *C*).

Data sheets also include parameters such as maximum ratings for current, power and temperature.

Maximum Ratings (T_C = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse voltage	V_R	60	Volts
Forward current	I_F	250	mA
RF power input*	P_{in}	5.0	Watts
Device dissipation @ T_A = 25°C Derate above 25°C	P_D	400 2.67	mW mW/°C
Device dissipation @ T_C = 25°C Derate above 25°C	P_C	2.0 13.3	Watts mW/°C
Junction temperature	T_J	+175	°C
Storage temperature range	T_{stg}	–65 to +200	°C

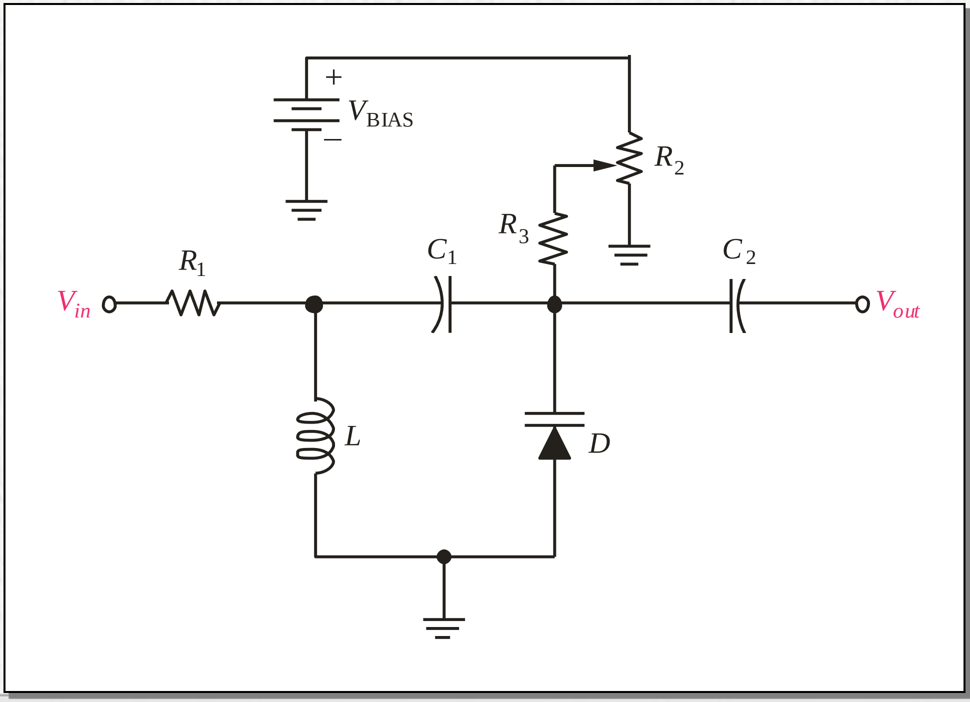
*The RF power input rating assumes that an adequate heat sink is provided

Summary

Varactor Diodes

Varactor diodes are used in tuning applications. The applied voltage controls the capacitance and hence the resonant frequency.

By varying R_2, the reverse bias on *D* is changed. This changes the capacitance, and hence the resonant frequency.



Summary

Optical Diodes

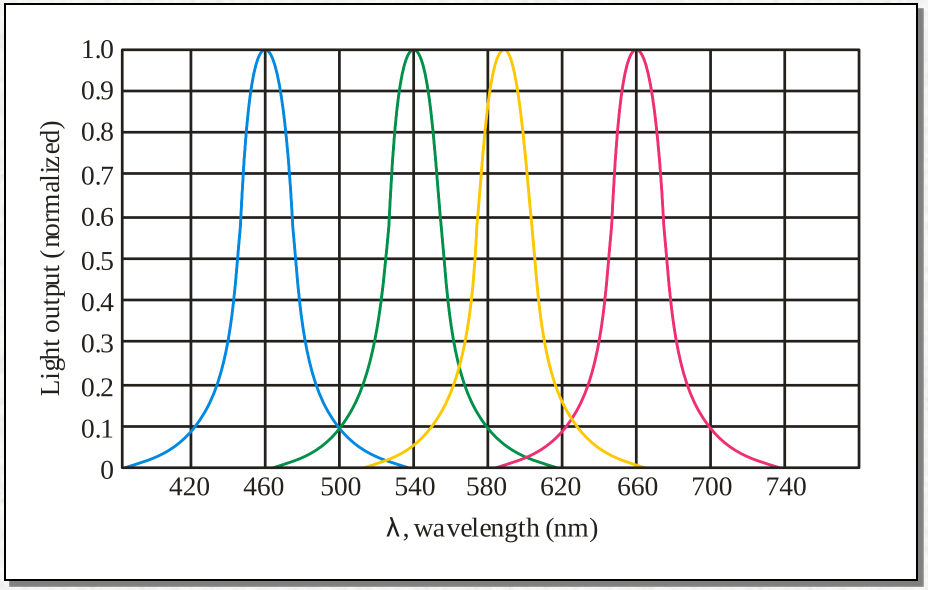
Diodes can be made to emit light (electroluminescence) or sense light. **Light-emitting diodes** (LEDs) vary widely in size and brightness – from small indicating lights and displays to high-intensity LEDs that are used in traffic signals, outdoor signs, and general illumination.

LEDs are very efficient light emitters, and extremely reliable, so even wider use of LEDs can be expected in the future. Even automobile headlamps may use LEDs in the future.

Summary

Optical Diodes

LEDs emit a specific range of wavelengths which depend on the construction and dye material used. The wavelength is given on the specification sheet. LEDs are available for visible light and infrared.



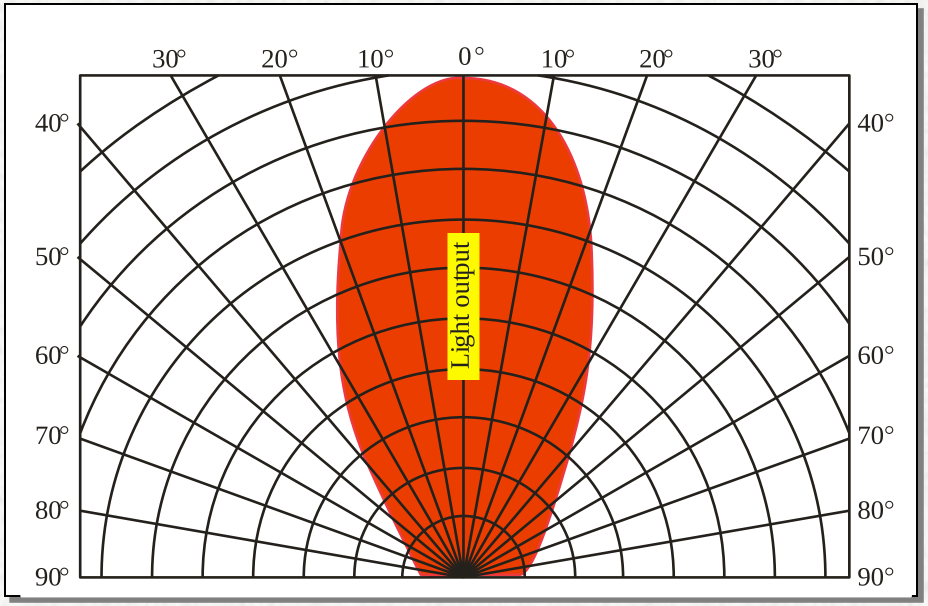
Question:

What is the peak wavelength of a green LED? 540 nm

Optical Diodes

Another characteristic shown in specification sheets is the radiation pattern for the LED. This plot is an example of a typical pattern in which light is concentrated in one direction.

A wider viewing angle will show a wider pattern such as the TLDR5400:



Summary

Optical Diodes

The forward voltage drop can vary from about 1.5 V to over 3 V depending on the type of diode, its color, and the amount of forward current. You need to take into account the specified maximum current allowed and the diode's forward drop when choosing a limiting resistor.

Example:

A certain bright red LED drops 2.2 V at a maximum current of 20 mA. What series resistor is required to limit the current to 20 mA from a 5.0 V source?

Solution:

$$R = \frac{V_s - V_{LED}}{I} = \frac{5.0\text{ V} - 2.2\text{ V}}{20\text{ mA}} = 180\ \Omega$$

Optical Diodes

Other specifications, such as maximum power dissipation are given on the manufacturer's specification sheet. To determine the power dissipated by the LED, multiply the forward voltage by the forward current.

Example:

A certain bright red LED drops 2.2 V at 20 mA. What power is dissipated by the LED?

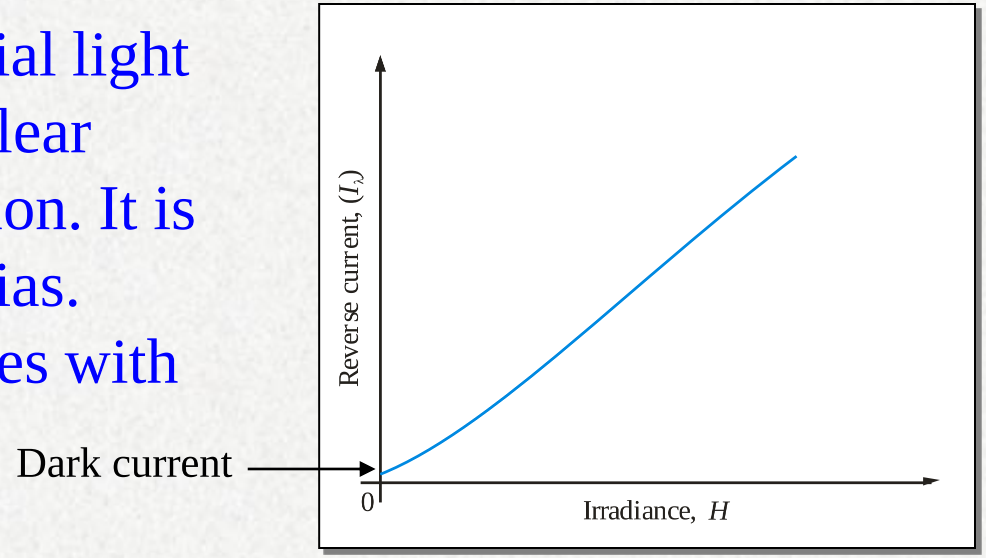
Solution:

$$P = IV = (20\text{ mA})(2.2\text{ V}) = 44\text{ mW}$$

Summary

Optical Diodes

A **photodiode** is a special light sensitive diode with a clear window to the *pn* junction. It is operated with reverse bias. Reverse current increases with greater incident light.



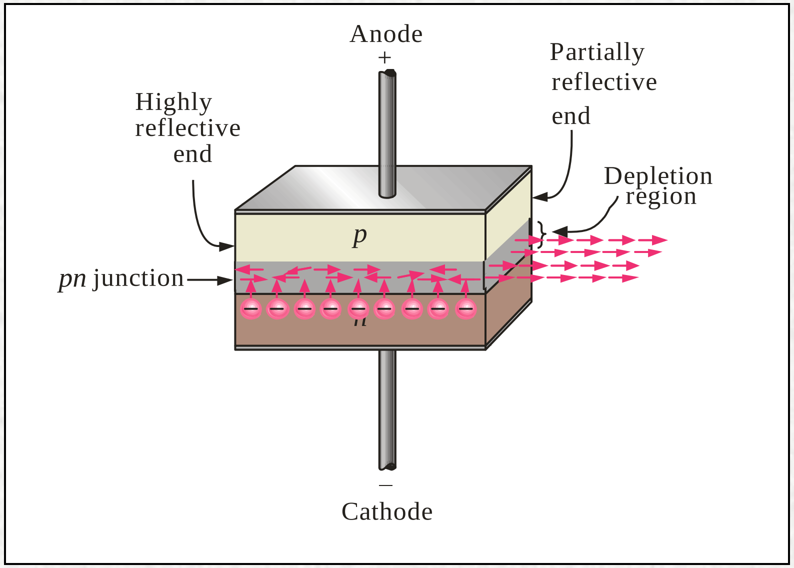
The tiny current that is present when the diode is not exposed to light is called **dark current**.

Summary

Laser Diodes

A **laser diode** converts an electrical signal into coherent (monochromatic) light. It produces an intense narrow beam of light from the recombination of electrons and holes in the depletion region.

The process is similar to the process that occurs in an LED, but a laser diode differs because the light emission is stimulated by a nearby photon to produce light that is "in-step" and occurs within an optical cavity.



Summary

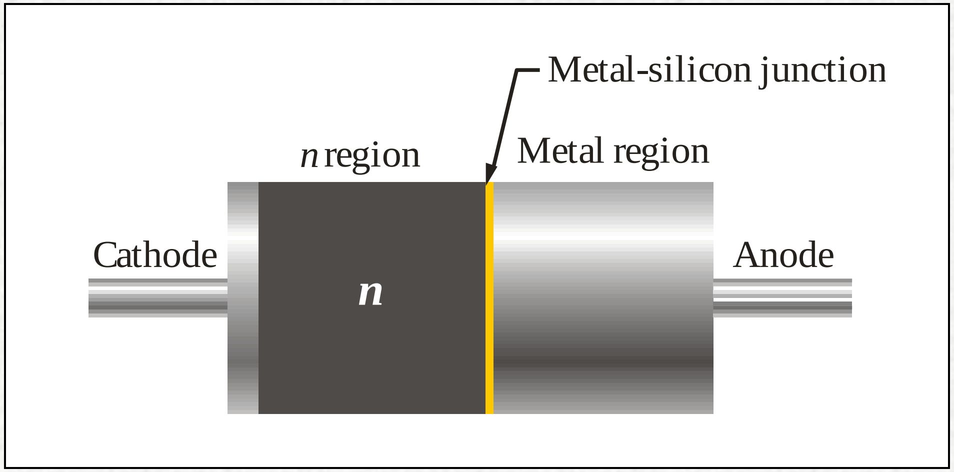
Laser Diodes

Laser diodes are the most common form of lasers made. They are used in applications such as bar code readers, fiber optic transmitters, CD readers, laser pointers, and instruments such as rangefinders.

Summary

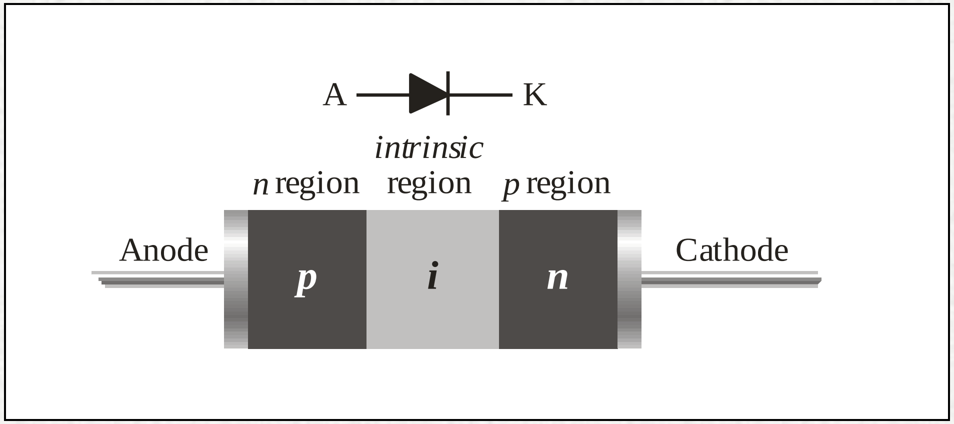
Schottky Diodes

A **Schottky diode** is a metal-to-semiconductor contact diode that is used primarily in high frequency and fast-switching applications. It has a low forward voltage drop and high efficiency but rather low reverse voltage rating.



PIN Diodes

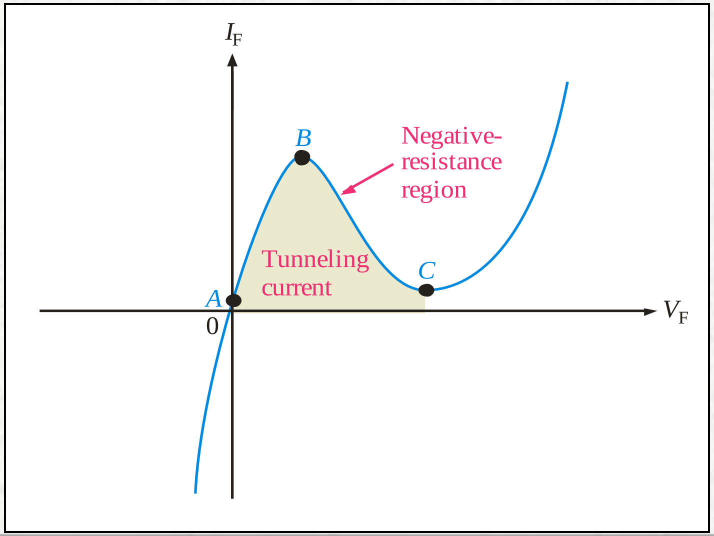
A ***PIN* diode** is a three layer diode consisting of a *p* and *n* layers separated by a narrow intrinsic layer. In microwave applications, the pin diode acts as a voltage-controlled resistor. Certain types are used as photodetectors in fiber optic systems.



Summary

Tunnel Diodes

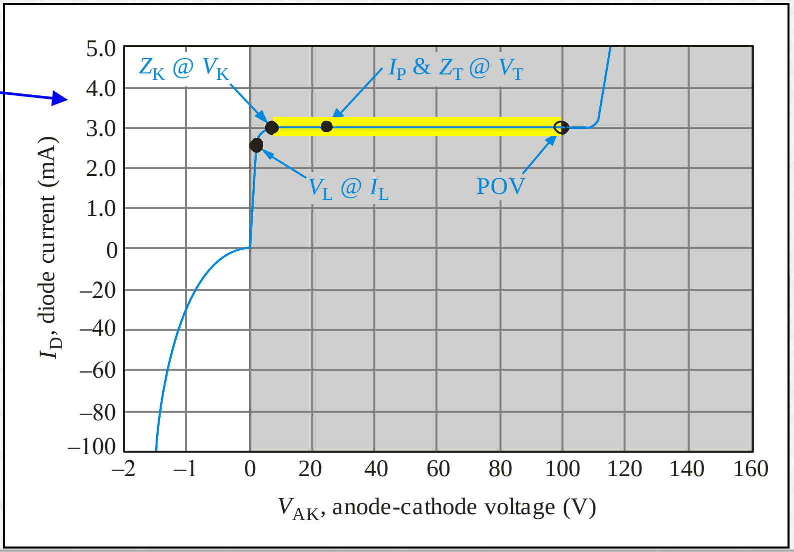
A **tunnel diode** has a characteristic curve that shows a negative resistance reading between *B* and *C* with a small forward voltage. The negative resistance region is unstable. Taking advantage of this characteristic, the tunnel diode can be used in an oscillator circuit at microwave frequencies.



Summary

Current Regulator Diodes

A **current-regulator diode** is a specialized diode that maintains a constant current when operated within a specific region. It is never operated with reverse bias. The constant current region is the horizontal portion of the characteristic curve.



Summary

Common Diode Symbols