BENHA UNIVERSITY
FACULTY OF ENGINEERING AT SHOUBRA

ECE-291
Electronic Engineering

Lecture #2
Diode Applications & Special Diodes

Instructor:
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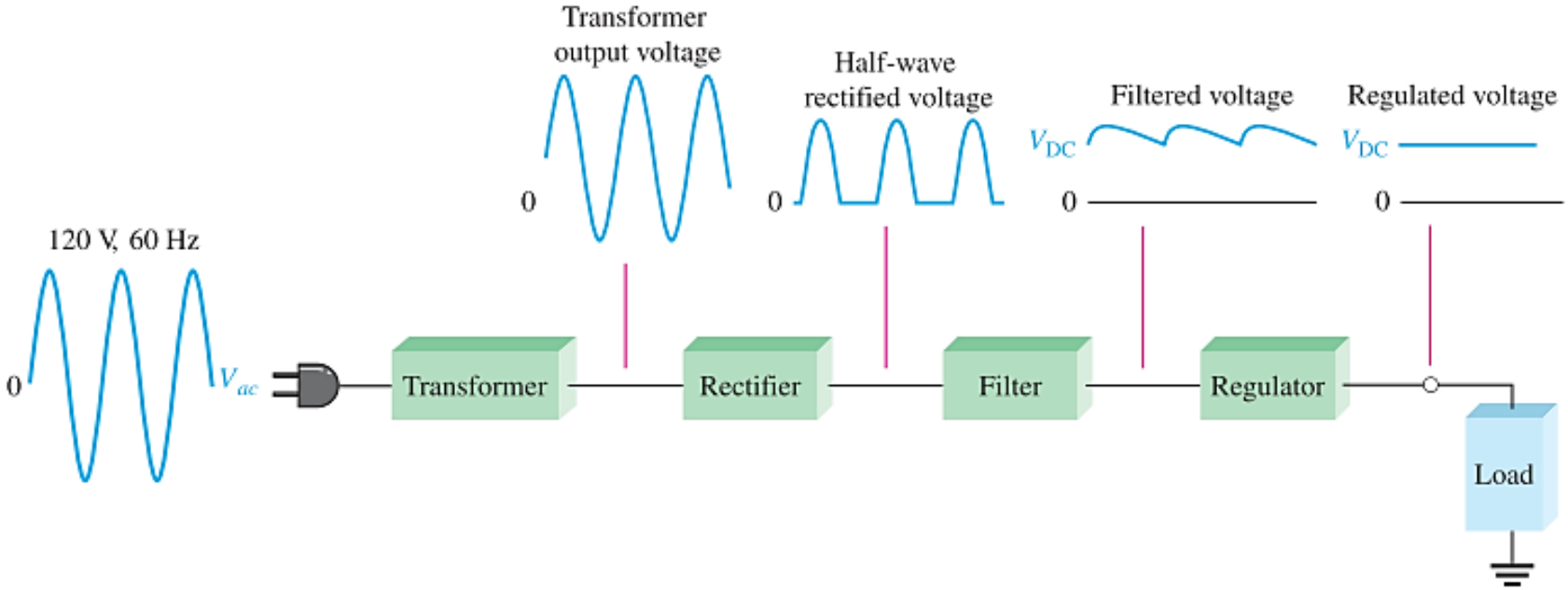
SPRING 2015

Agenda

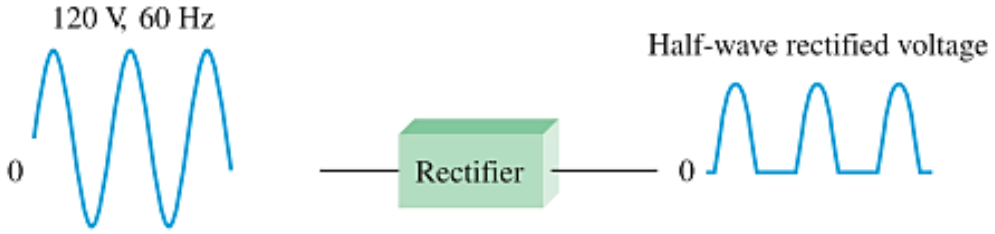
- Half-wave Rectifier
- Full-wave Rectifier
- Power Supply Regulators
- Zener Diode
- LED
- Photodiode

DIODE APPLICATIONS

Rectifiers
Half-wave Rectifiers

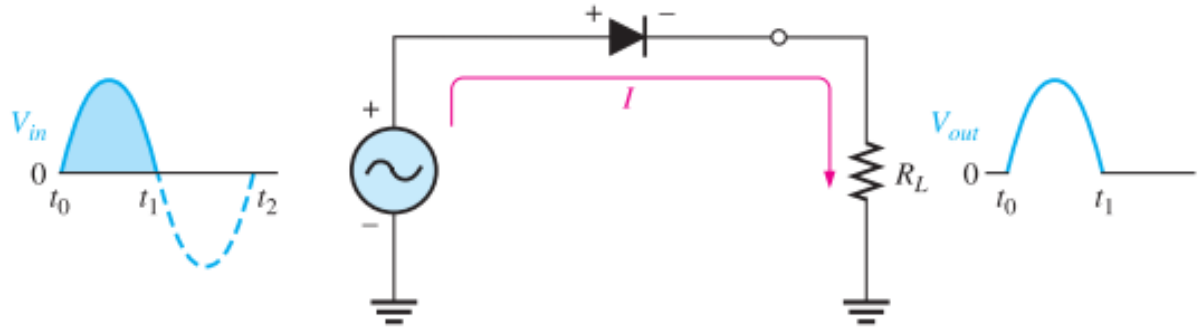


(a) Complete power supply with transformer, rectifier, filter, and regulator

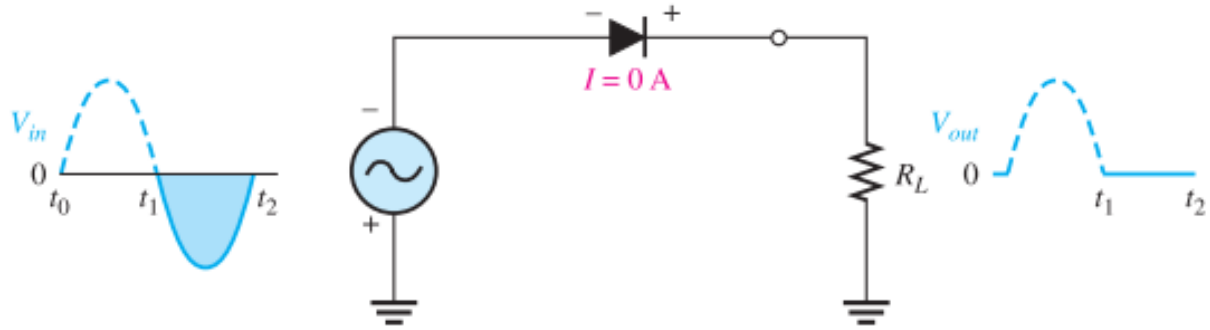


(b) Half-wave rectifier

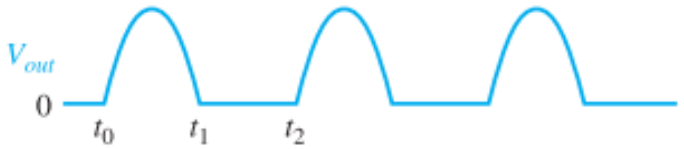
Half-wave Rectifier Operation



(a) During the positive alternation of the 60 Hz input voltage, the output voltage looks like the positive half of the input voltage. The current path is through ground back to the source.



(b) During the negative alternation of the input voltage, the current is 0, so the output voltage is also 0.

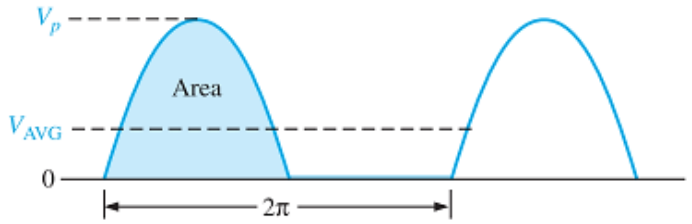


(c) 60 Hz half-wave output voltage for three input cycles

Average Voltage & PIV

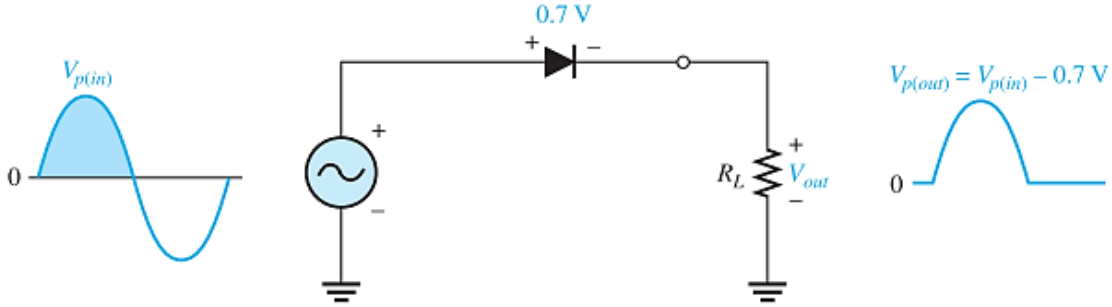
- Average Value of the Half-Wave Output Voltage

$$V_{AVG} = \frac{V_p}{\pi}$$



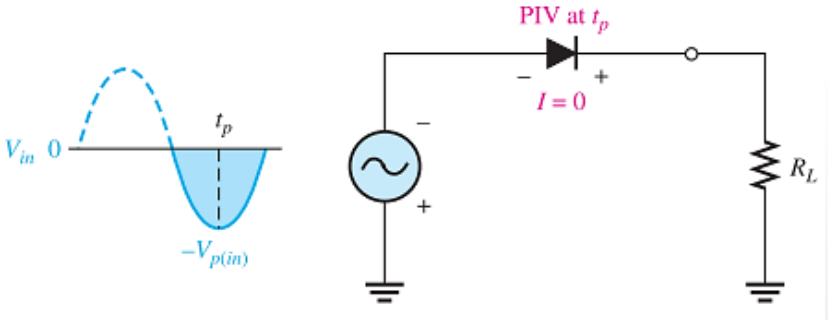
- Effect of the Barrier Potential

$$V_{p(out)} = V_{p(in)} - 0.7\,\text{V}$$



- The peak inverse voltage (**PIV**) equals the peak value of the input voltage

$$\text{PIV} = V_{p(in)}$$

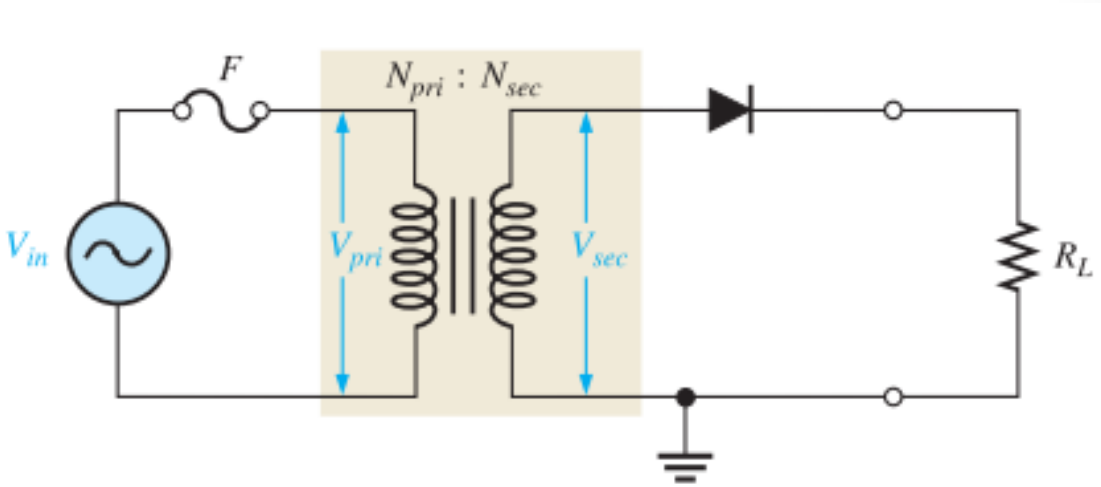


The diode must be capable of withstanding this amount of repetitive reverse voltage.

Transformer Coupling

$$V_{sec} = nV_{pri}$$

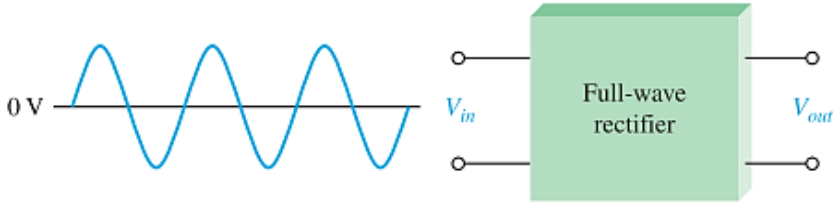
n : turns ratio
V_{sec}: secondary voltage
V_{pri} : primary voltage



$$V_{p(out)} = V_{p(sec)} - 0.7\ \text{V}$$

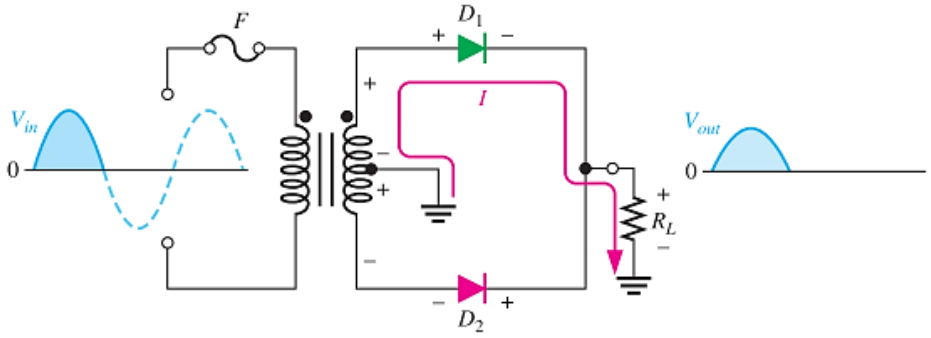
$$\text{PIV} = V_{p(sec)}$$

Rectifiers
Full-wave Rectifiers

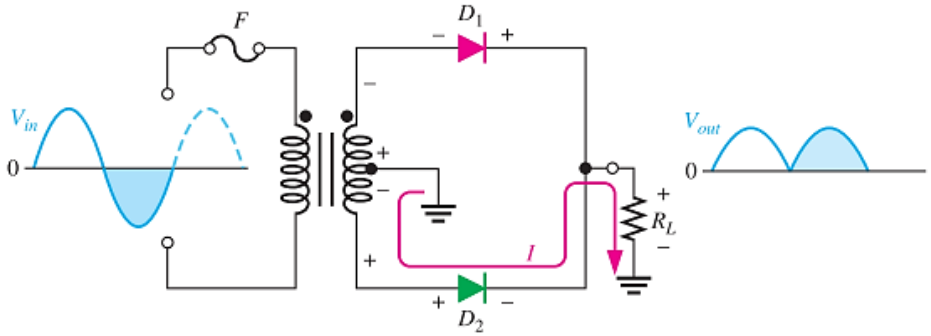


$$V_{AVG} = \frac{2V_p}{\pi}$$

- **Center-tapped Full-wave Rectifier**



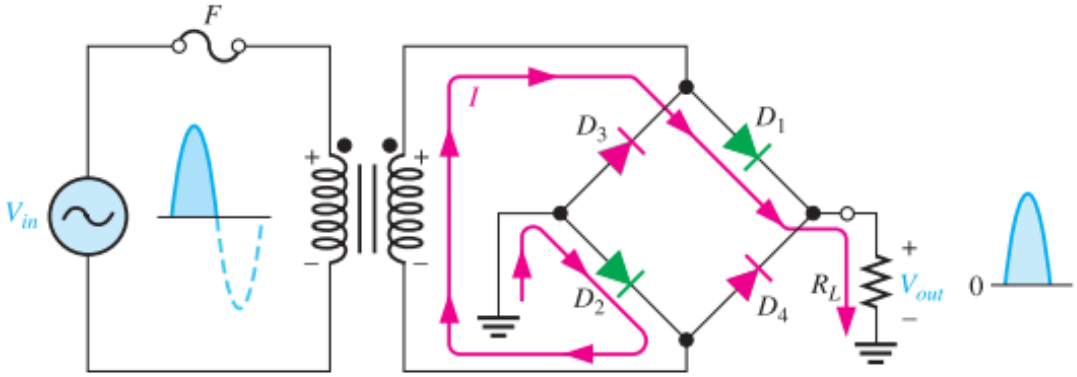
(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.



(b) During negative half-cycles, D_2 is forward-biased and D_1 is reverse-biased.

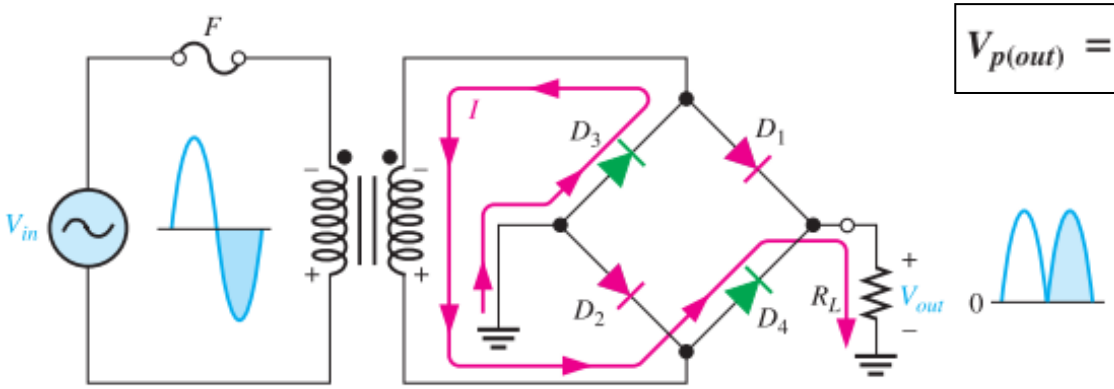
$$V_{out} = \frac{V_{sec}}{2} - 0.7\,\text{V}$$

Bridge Full-Wave Rectifier Operation



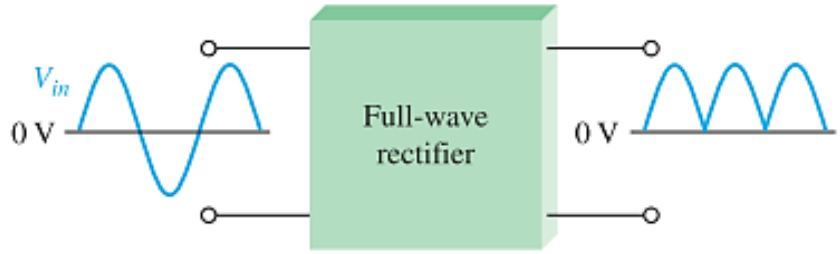
(a) During the positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

$$V_{p(out)} = V_{p(sec)} - 1.4\,\text{V}$$

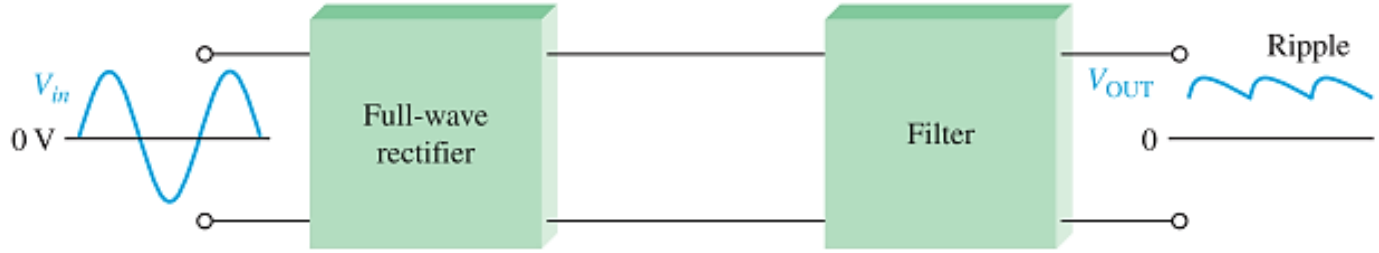


(b) During the negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

POWER SUPPLY FILTERS

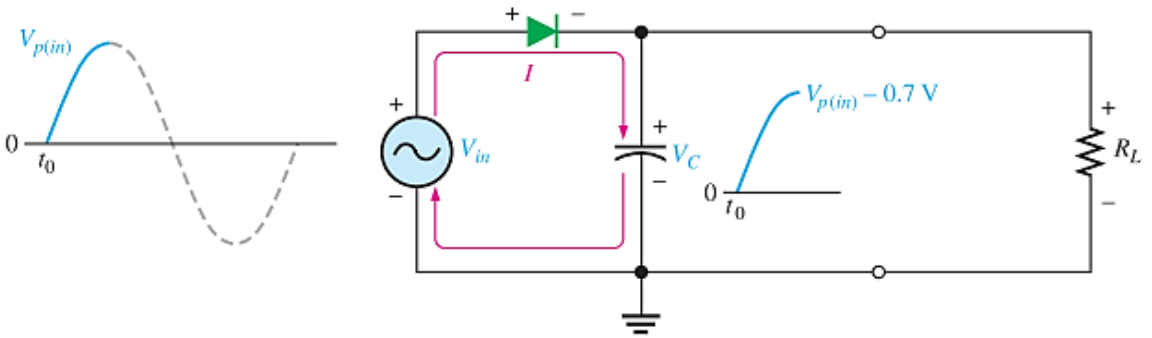


(a) Rectifier without a filter

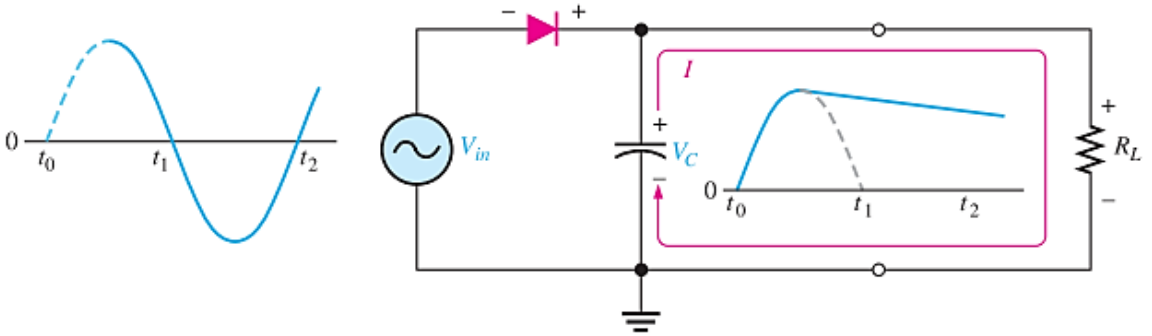


(b) Rectifier with a filter (output ripple is exaggerated)

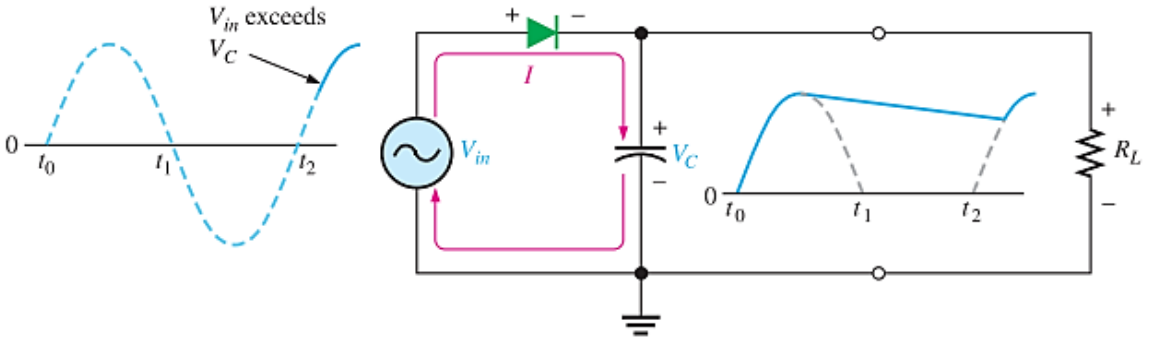
Capacitor -Input Filter



(a) Initial charging of the capacitor (diode is forward-biased) happens only once when power is turned on.



(b) The capacitor discharges through R_L after peak of positive alternation when the diode is reverse-biased. This discharging occurs during the portion of the input voltage indicated by the solid dark blue curve.

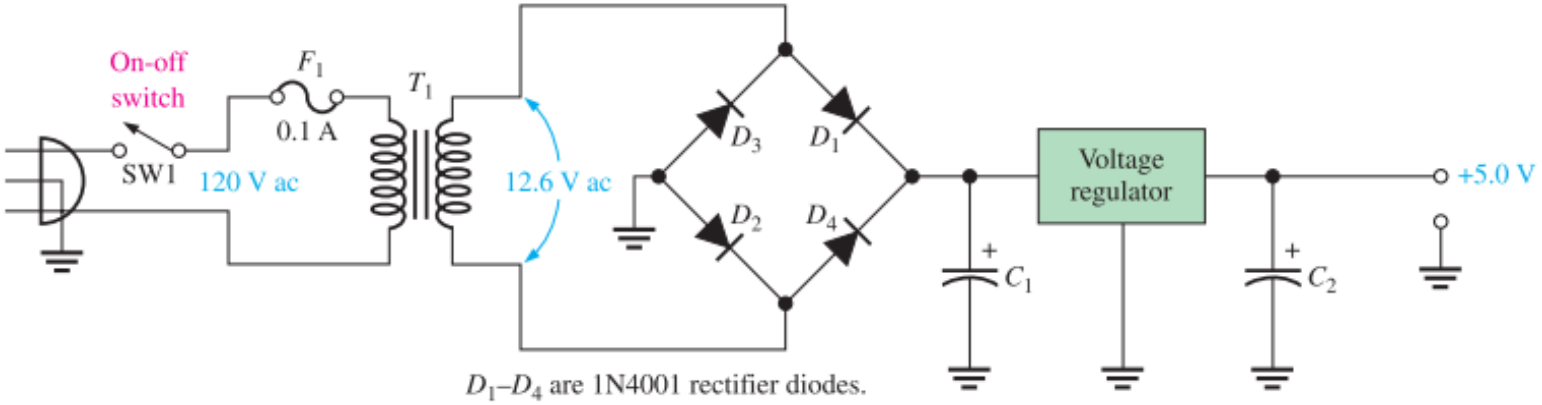


(c) The capacitor charges back to peak of input when the diode becomes forward-biased. This charging occurs during the portion of the input voltage indicated by the solid dark blue curve.

POWER SUPPLY REGULATORS

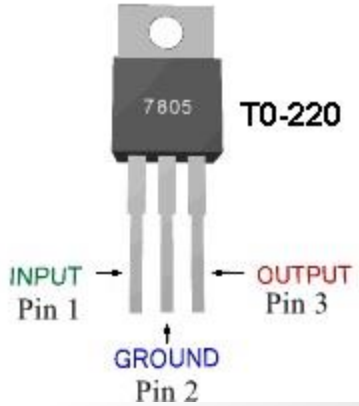
- While filters can reduce the ripple from power supplies to a low value, the most effective approach is a combination of a capacitor-input filter used with a voltage regulator.

A basic +5.0 V regulated power supply



D_1–D_4 are 1N4001 rectifier diodes.

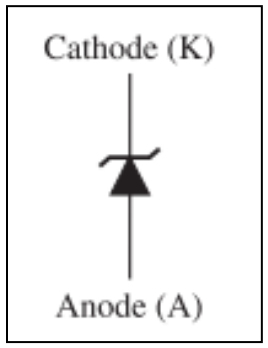
7805 Voltage Regulator IC →

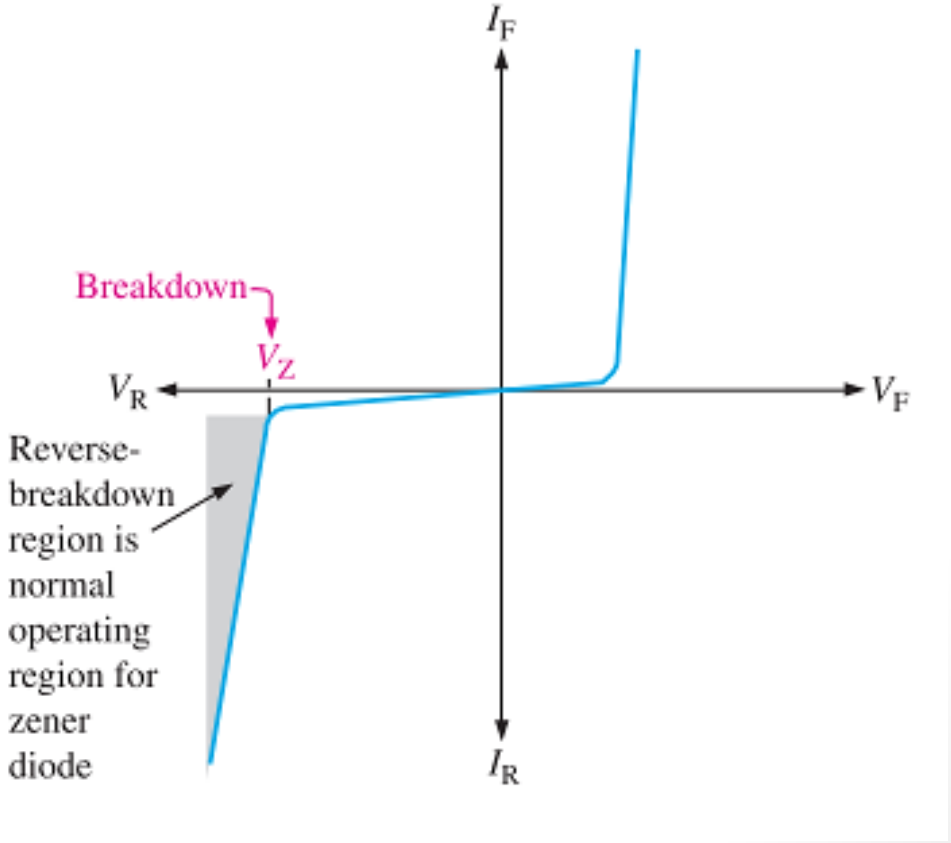


SPECIAL PURPOSE DIODES

The Zener Diode

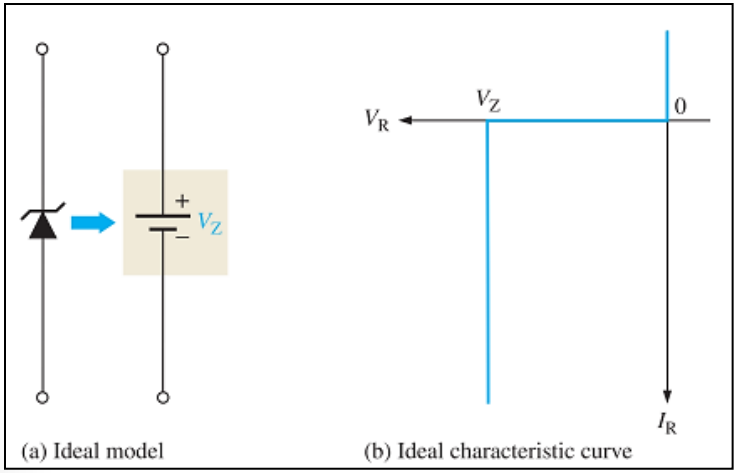
- A zener diode is a silicon pn junction device that is designed for operation in the reverse-breakdown region.
- The breakdown voltage of a zener diode is set by carefully controlling the doping level during manufacture.



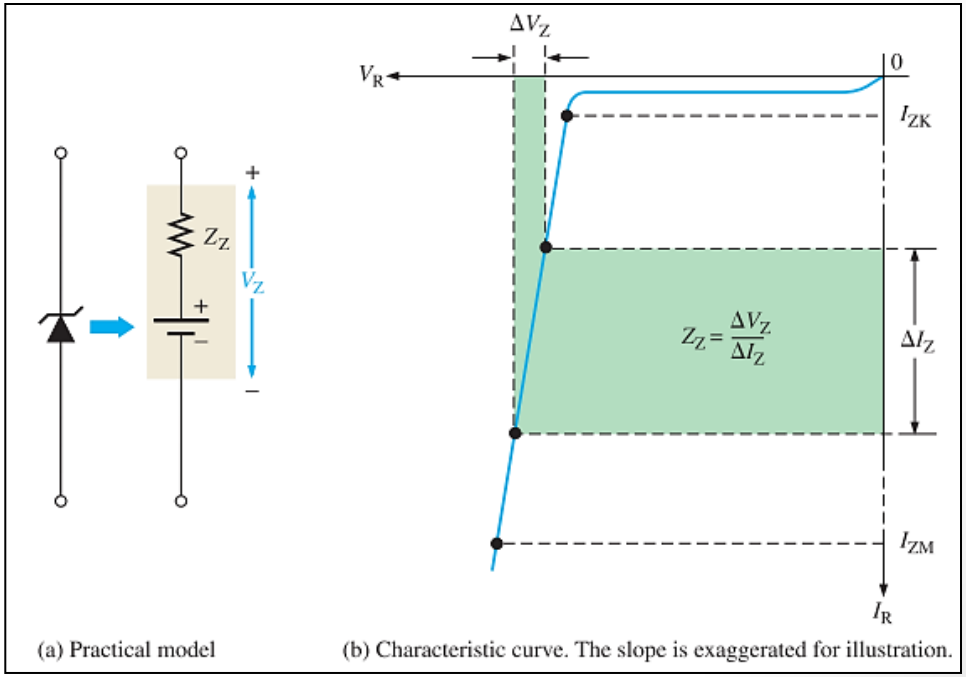


Zener Equivalent Circuits

- Zener is used as Regulator
- Two Models
  - Ideal Model
  - Practical Model



(a) Ideal model (b) Ideal characteristic curve



(a) Practical model (b) Characteristic curve. The slope is exaggerated for illustration.

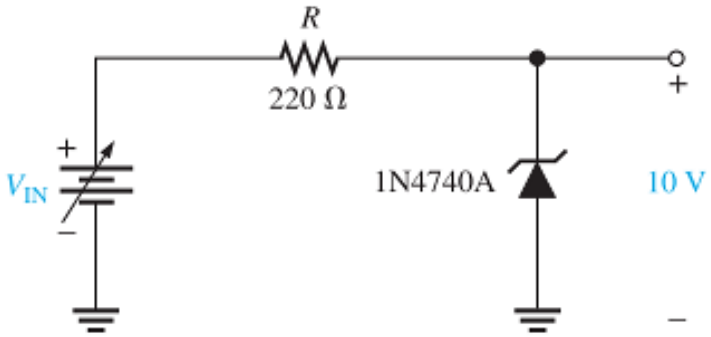
Zener Regulation

- **Zener Regulation with a Variable Input Voltage**

$$I_{ZM} = \frac{P_{D(max)}}{V_Z} = \frac{1\text{ W}}{10\text{ V}} = 100\text{ mA}$$

$$V_R = I_{ZK}R = (0.25\text{ mA})(220\ \Omega) = 55\text{ mV}$$

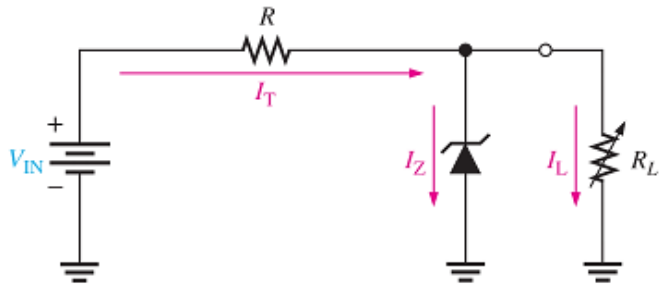
$$V_{IN(min)} = V_R + V_Z = 55\text{ mV} + 10\text{ V} = 10.055\text{ V}$$



$$V_R = I_{ZM}R = (100\text{ mA})(220\ \Omega) = 22\text{ V}$$

$$V_{IN(max)} = 22\text{ V} + 10\text{ V} = 32\text{ V}$$

- **Zener Regulation with a Variable Load**

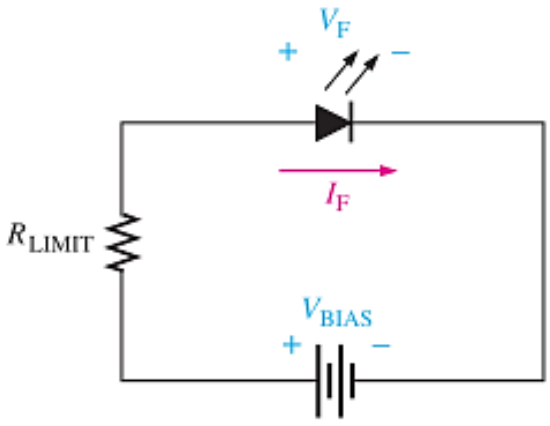


Check EXAMPLE 3–6 !

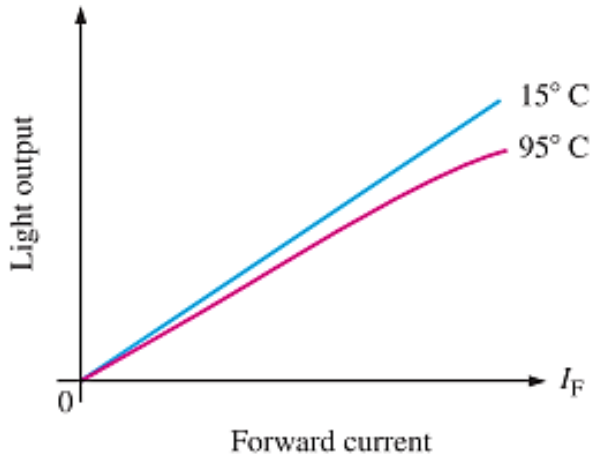
Optical Diodes
The Light-Emitting Diode (LED)

Basic operation :

- When the device is forward-biased, electrons cross the pn junction from the n-type material and recombine with holes in the p-type material.
- The difference in energy between the electrons and the holes corresponds to the energy of visible light.
- When recombination takes place, the recombining electrons release energy in the form of ***photons***.



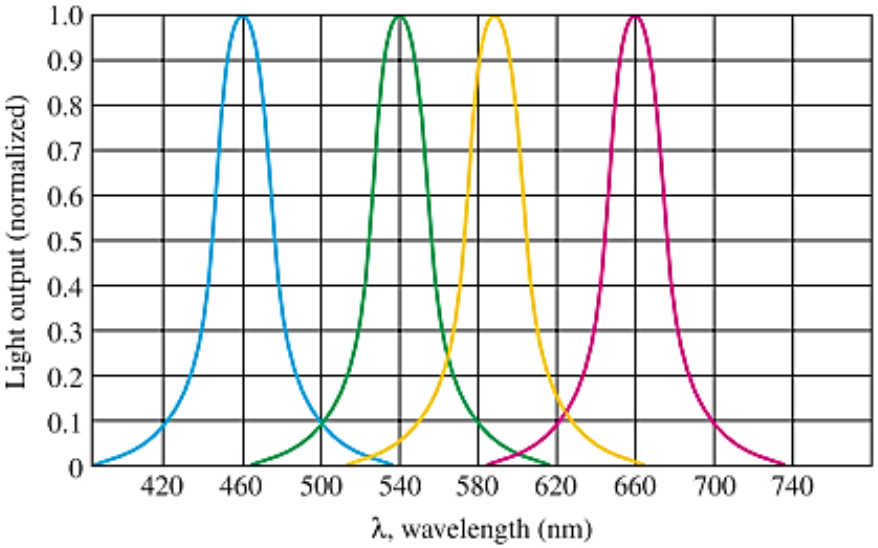
(a) Forward-biased operation



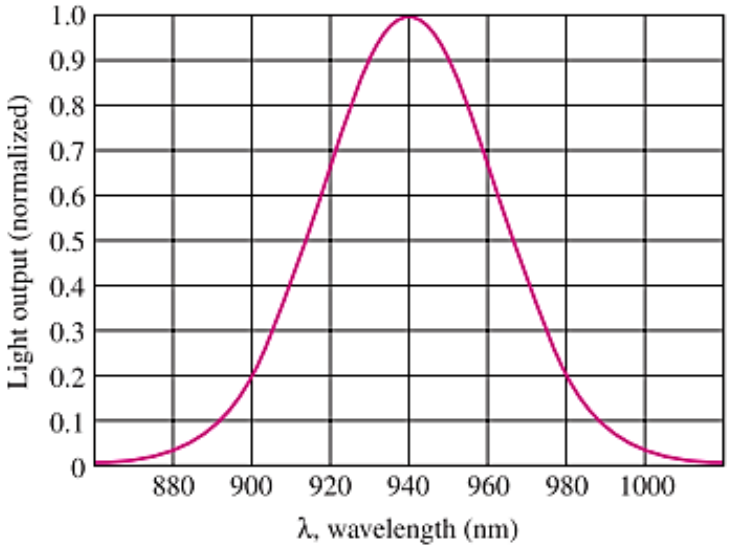
(b) General light output versus forward current for two temperatures

Light Emission

- An LED emits light over a specified range of wavelengths.
- Examples of typical spectral output curves for LEDs:



(a) Visible light



(b) Infrared (IR)

Typical LEDs

(a) Typical small LEDs for indicators

Helion 12 V overhead light with socket and module

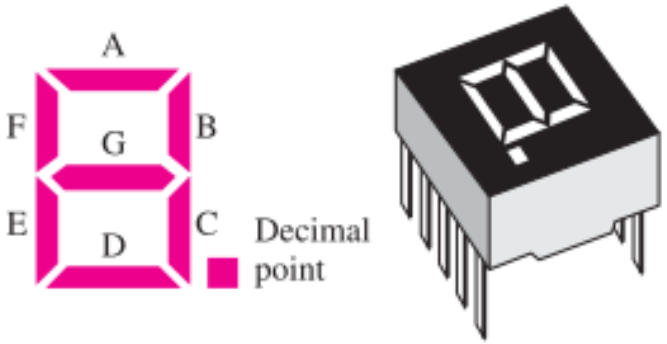
120 V, 3.5 W screw base for low-level illumination

120 V, 1 W small screw base candelabra style

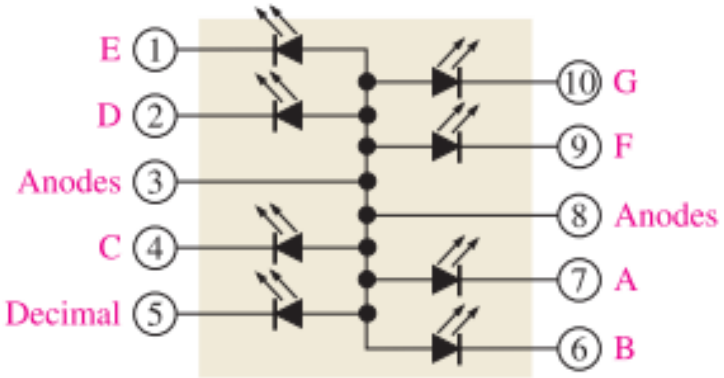
6 V, bayonet base for flashlights, etc.

(b) Typical LEDs for lighting applications

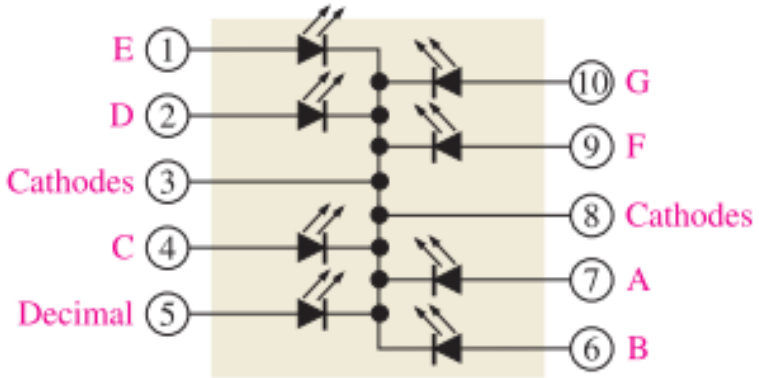
LED Application
7-Segment Display



(a) LED segment arrangement and typical device



(b) Common anode

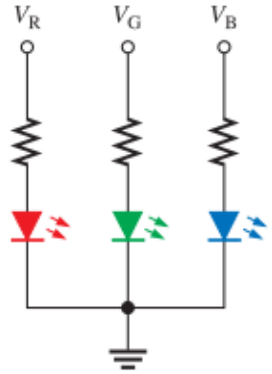


(c) Common cathode

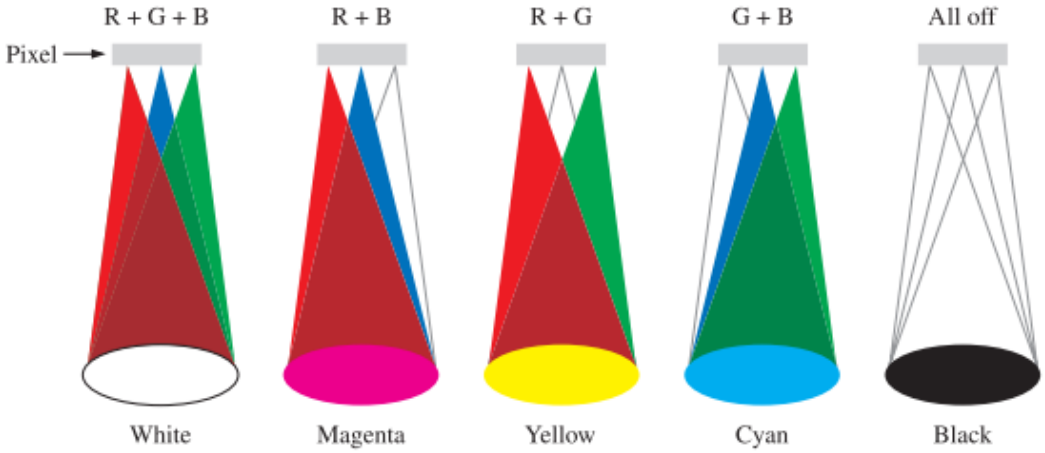
LED Application
LED Displays

- The concept of an RGB pixel used in LED display screens.

(a) Basic pixel



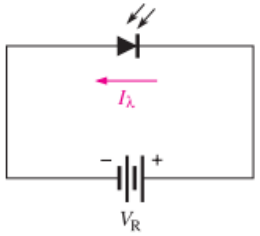
(b) Pixel circuit



(c) Examples of different combinations of equal amounts of primary colors

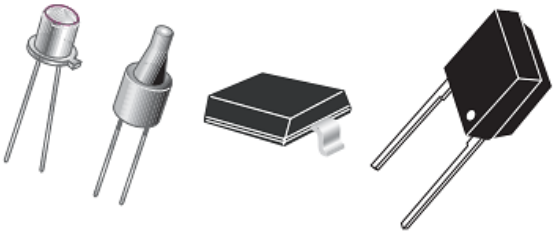
Optical Diodes
The Photodiode

- The photodiode is a device that operates in reverse bias where I is the reverse light current.
- The photodiode has a small transparent window that allows light to strike the pn junction.
- Internal Resistance changes by the amount of light.

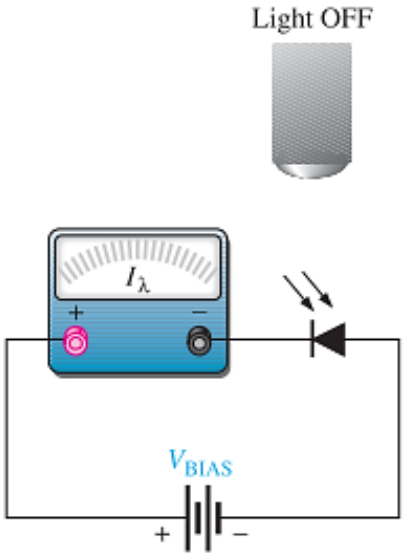


(a) Reverse-bias operation using standard symbol

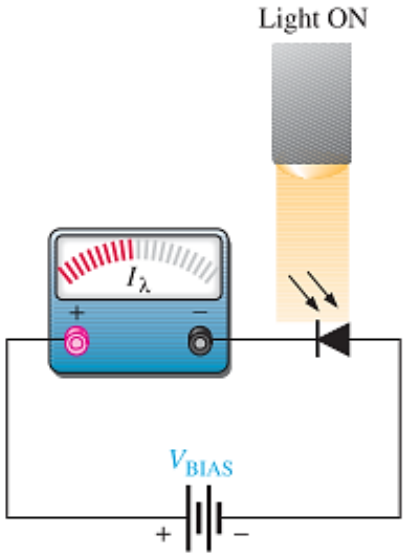
(c) Alternate symbol



(b) Typical devices



(a) No light, no current except negligible dark current



(b) Where there is incident light, resistance decreases and there is reverse current.

- For more details, refer to:
  - Chapter 2,3, T. Floyd, **Electronic Devices and Circuit Theory**, 11th edition, Prentice Hall.
- The lecture is available online at:
  - *http://bu.edu.eg/staff/ahmad.elbanna-courses/12136*
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg