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UNIVERSITÉ MOULAY ISMAÏL



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FACULTÉ DES SCIENCES

Course Optoelectronic

Parcours électronique S6 2025-2026

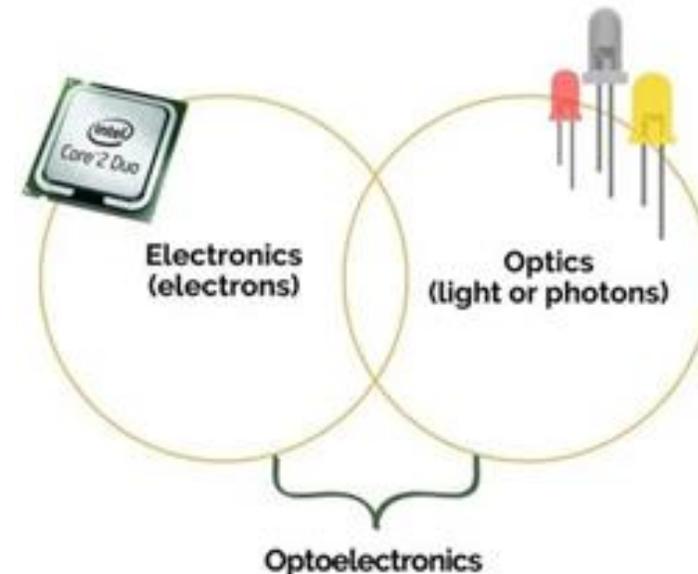
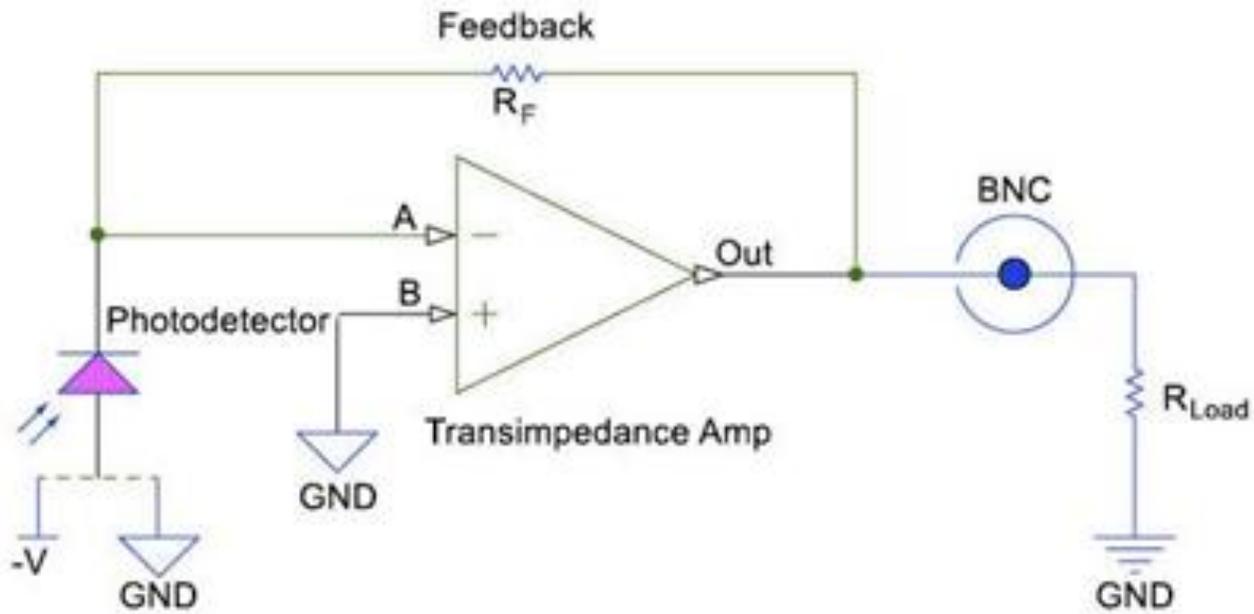
Pr. Omar EL OUTASSI

Chapitre 3: Optoelectronic detectors

- Understand different Optoelectronic detectors
- Explain Photoconductors
- Explain different types of Photodiodes
- Understand Phototransistors

Introduction to Optoelectronic Detectors

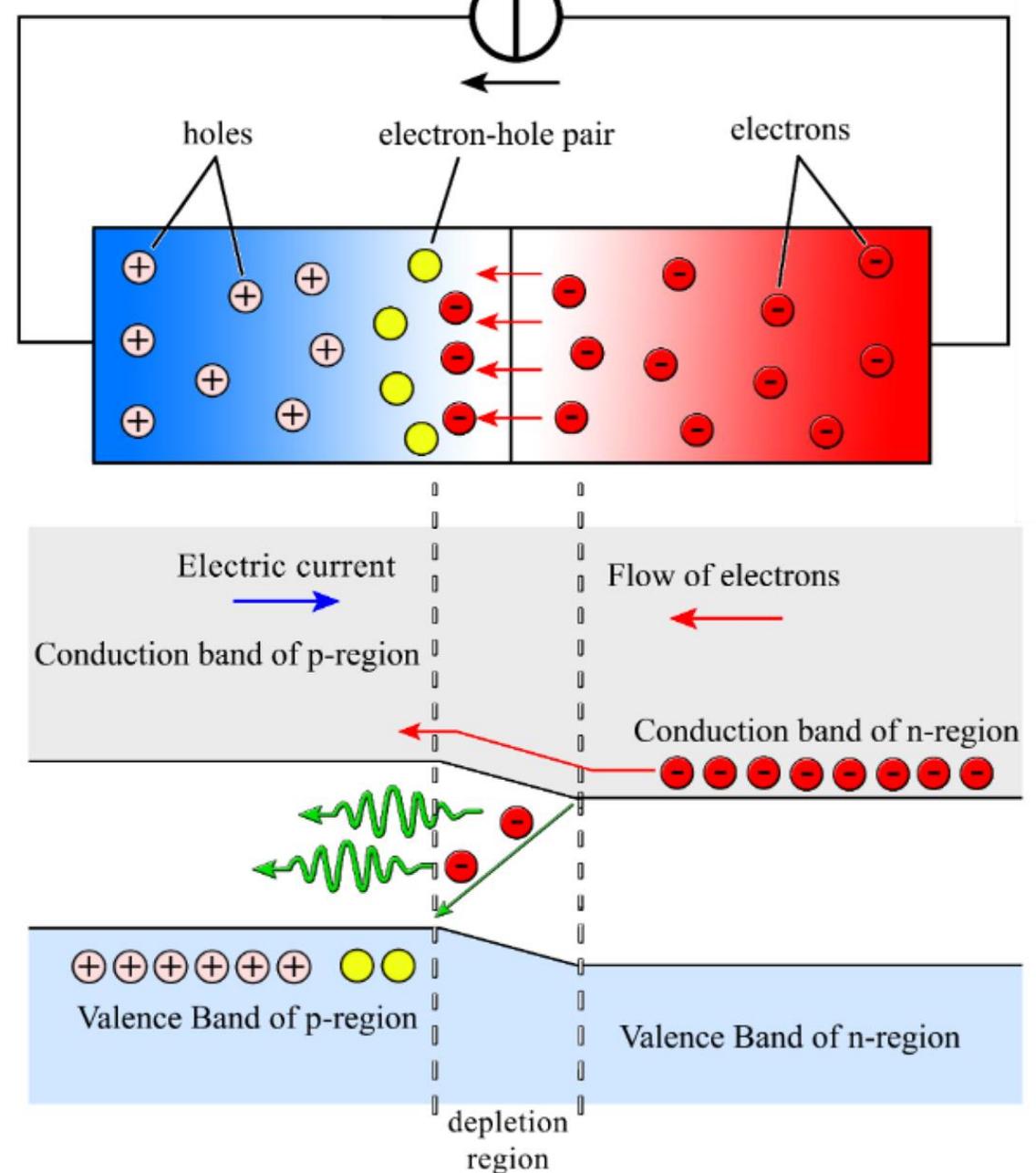
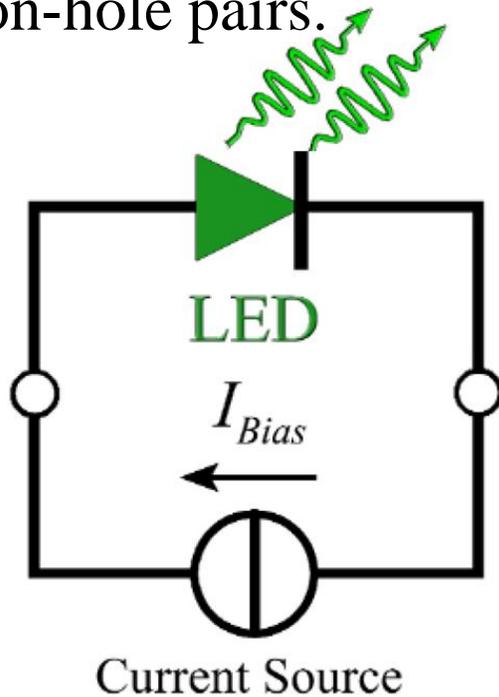
- **Definition:** Devices that convert optical signals (light/photons) into electrical signals (current or voltage).



Introduction to Optoelectronic Detectors

➤ Fundamental Principle:

Based on the **internal photoelectric effect**, where incident photons excite electrons from the valence band to the conduction band, creating electron-hole pairs.



Introduction to Optoelectronic Detectors

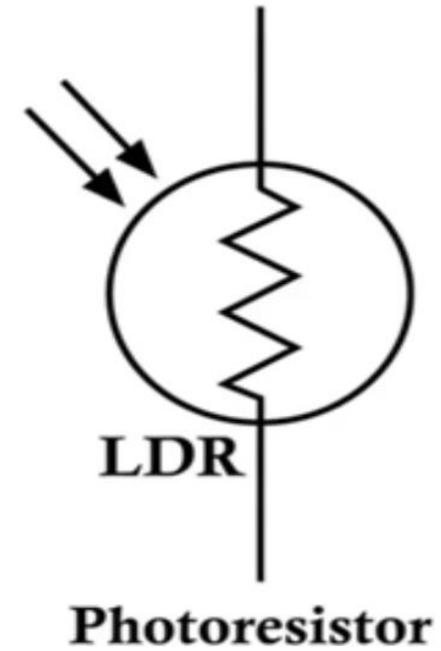
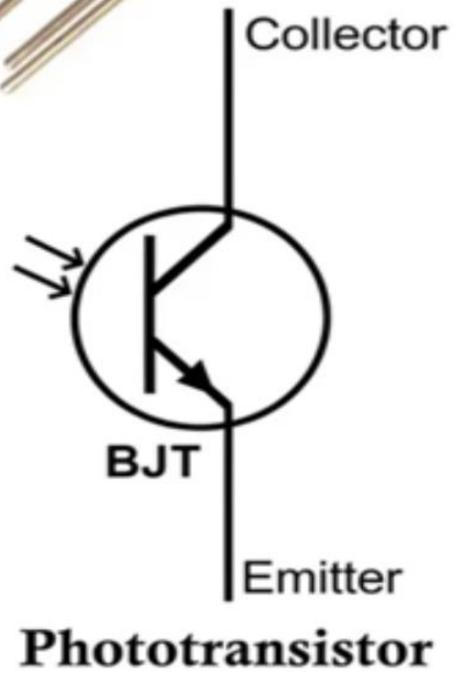
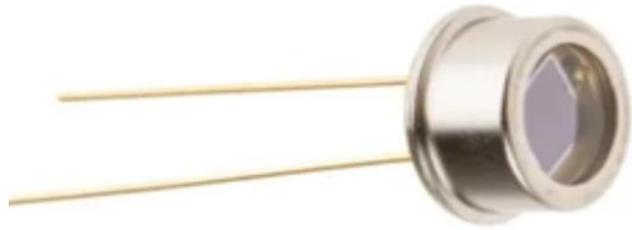
➤ Key Performance Metrics:

- **Responsivity:** Ratio of photocurrent to incident optical power (A/W).

$$R = \frac{I_{PH}}{P_{opt}} = \eta \frac{\lambda \cdot q}{h \cdot c} = \frac{\text{number of collected electrons}}{\text{number of incident photons}} \cdot 100\% \cdot \frac{\lambda \cdot q}{h \cdot c}$$

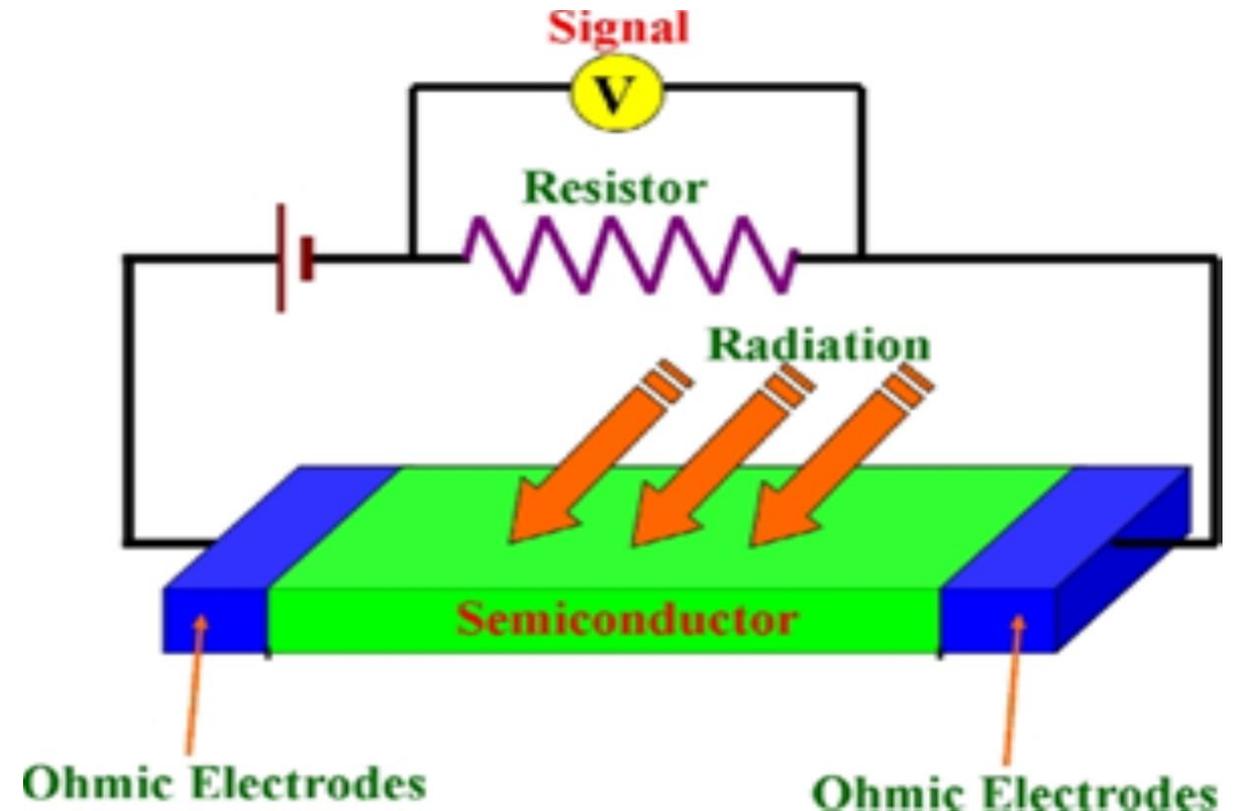
- **Quantum Efficiency:** The percentage of incident photons that contribute to the electrical current
- **Response Time:** How quickly the detector responds to changes in light intensity.

Photoconductors



Photoconductors

- **Mechanism:** When light hits a semiconductor material, its electrical conductivity increases as more free charge carriers are generated.
- **Operating Principle:** In the dark, the material has high resistance. Under illumination, the resistance drops significantly.



Photoconductors

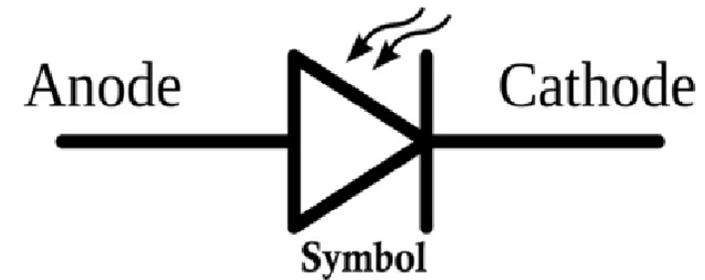
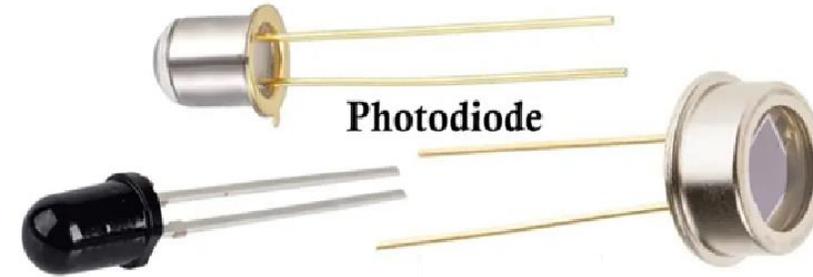
➤ **Characteristics:**

- **Gain:** High internal gain (a single photon can result in many electrons flowing through the circuit).
- **Speed:** Generally slower response times compared to photodiodes due to carrier lifetime limitations.

➤ **Common Materials:** Cadmium Sulfide (CdS) and Lead Sulfide (PbS).

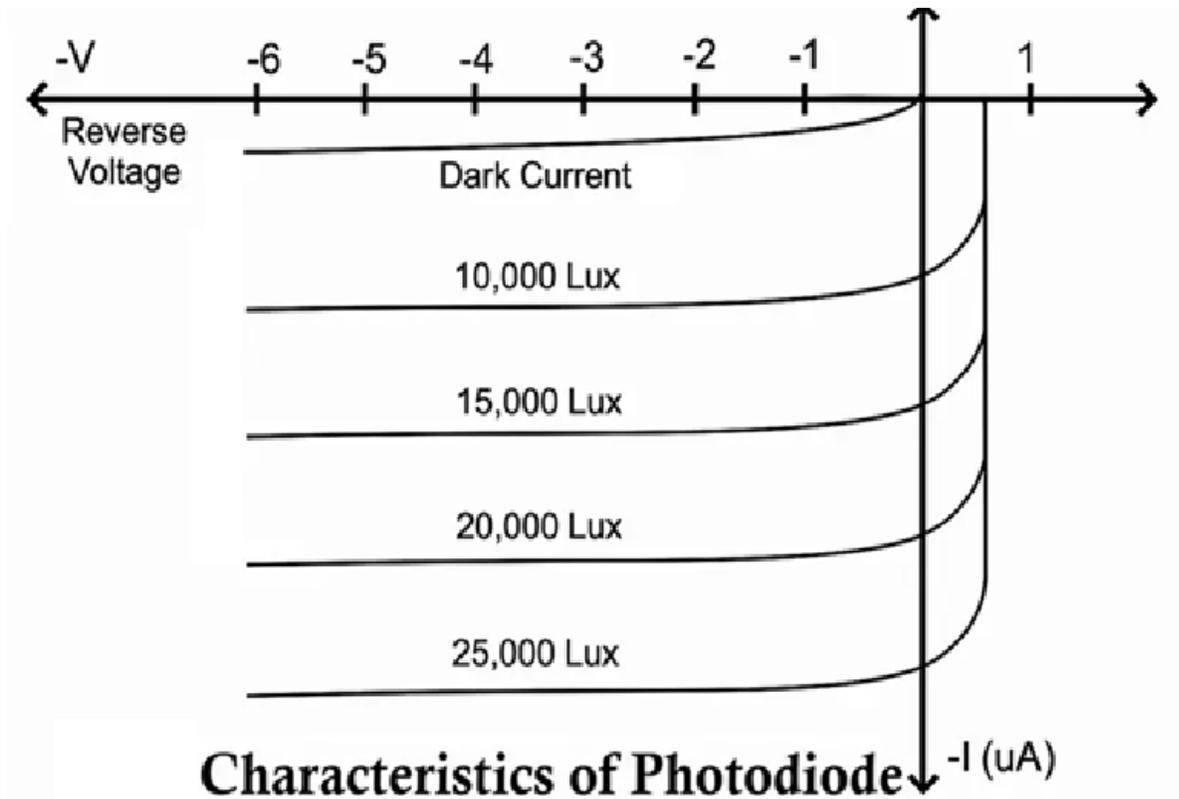
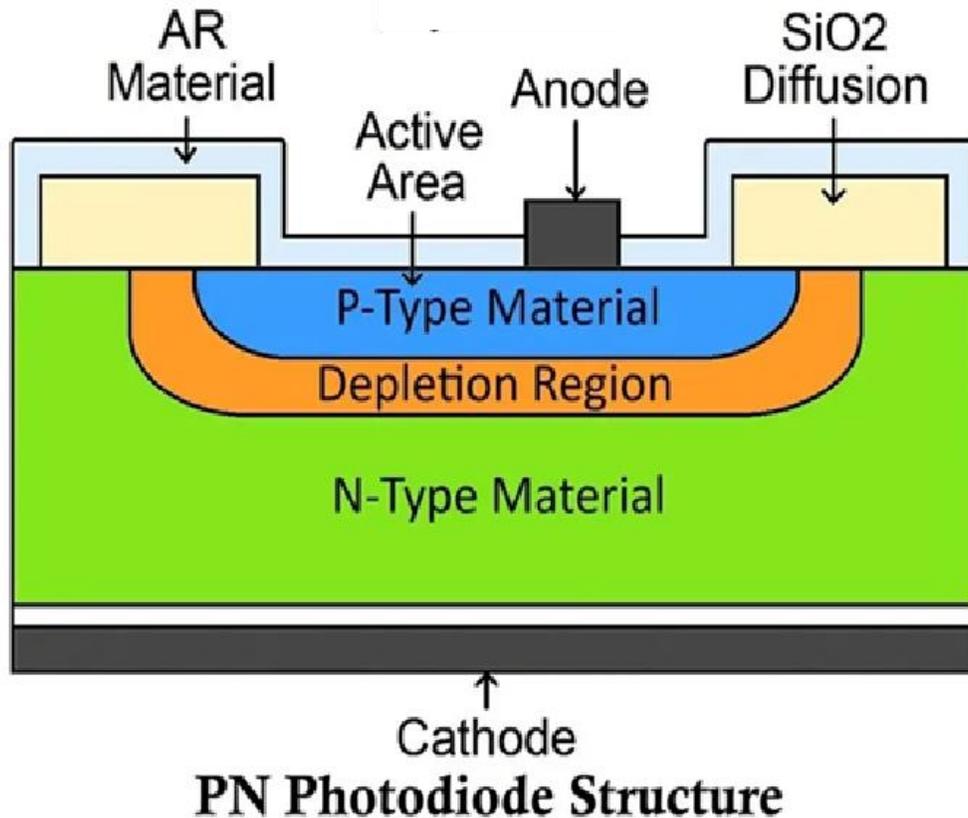
Photodiodes and PN Junction

- **Structure:**
- **Operation:.**
- **Advantages:**
- **Application Areas:**



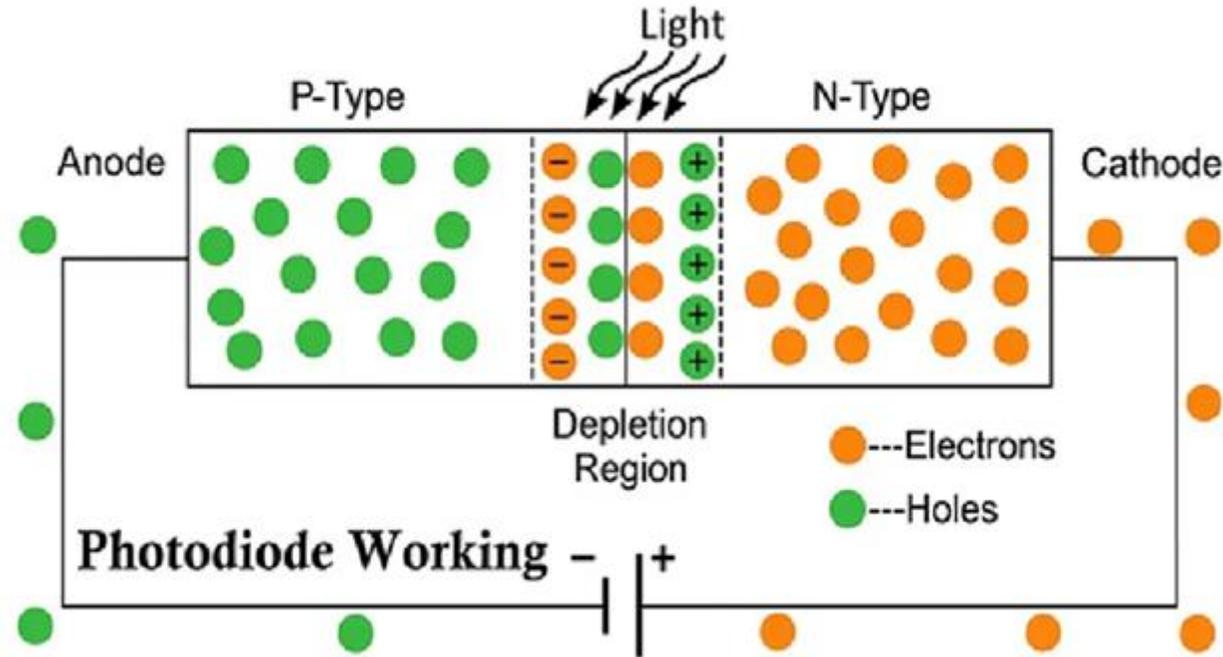
Photodiodes and PN Junction

- **Structure:** A semiconductor P-N junction operated under **reverse bias**.



Photodiodes and PN Junction

- **Operation:** Photons absorbed in the depletion region create electron-hole pairs. The internal electric field sweeps these carriers to the terminals, creating a photocurrent.

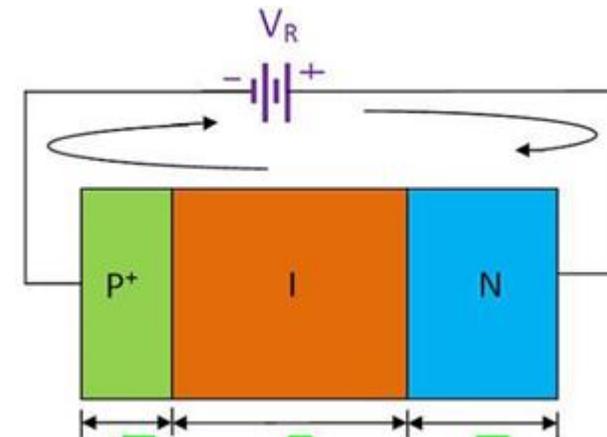
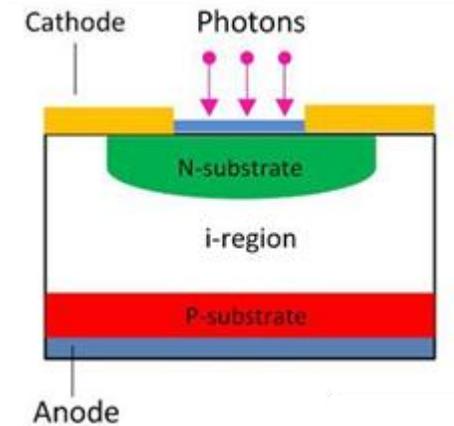
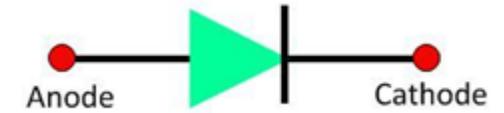


- **Advantages:** High linearity, low noise, and very fast response times.
- **Application Areas:** Optical fiber communications, remote controls, and medical imaging.

Specialized Photodiode Types

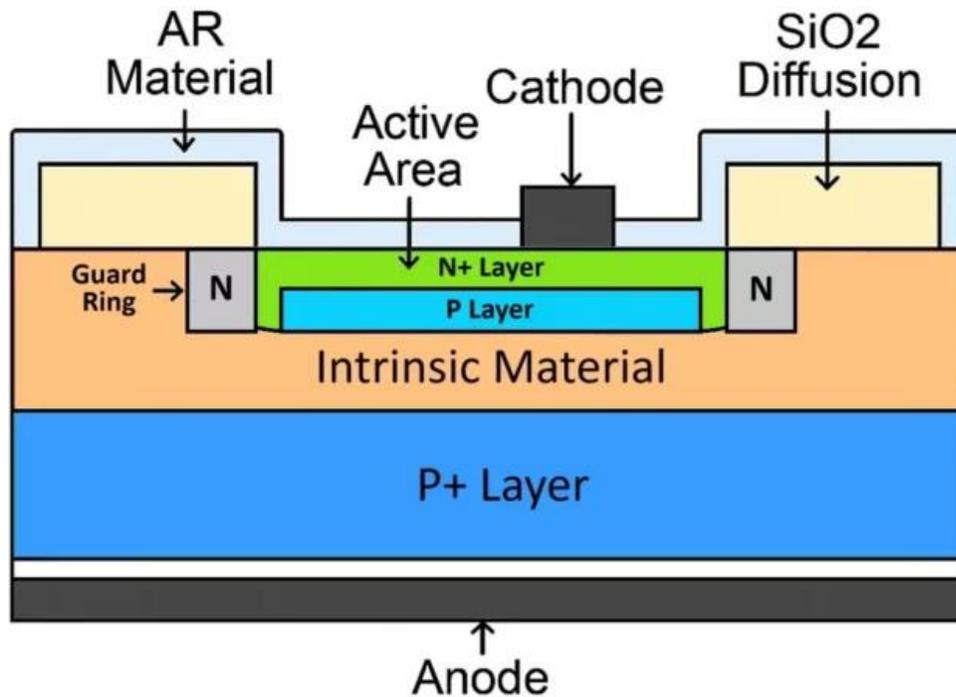
➤ PIN Photodiode:

- Features an "Intrinsic" (undoped) layer between the P and N layers.
- **Benefit:** Increases the depletion width, allowing for higher quantum efficiency and lower junction capacitance (faster speed).

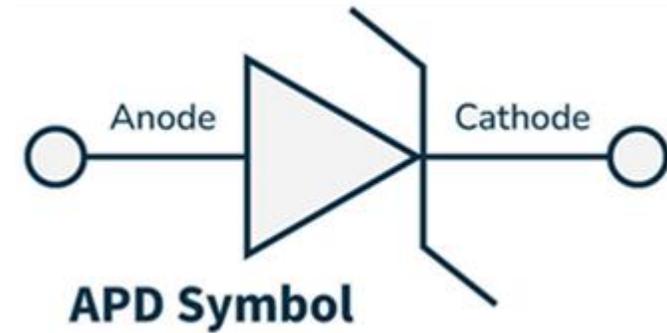


Specialized Photodiode Types

➤ Avalanche Photodiode (APD):



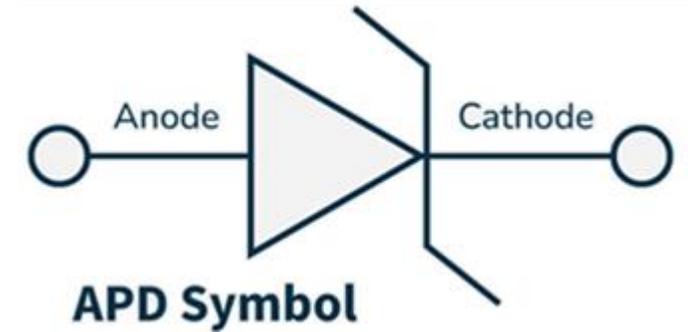
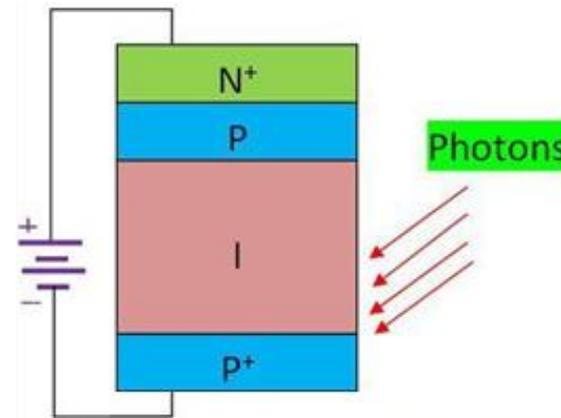
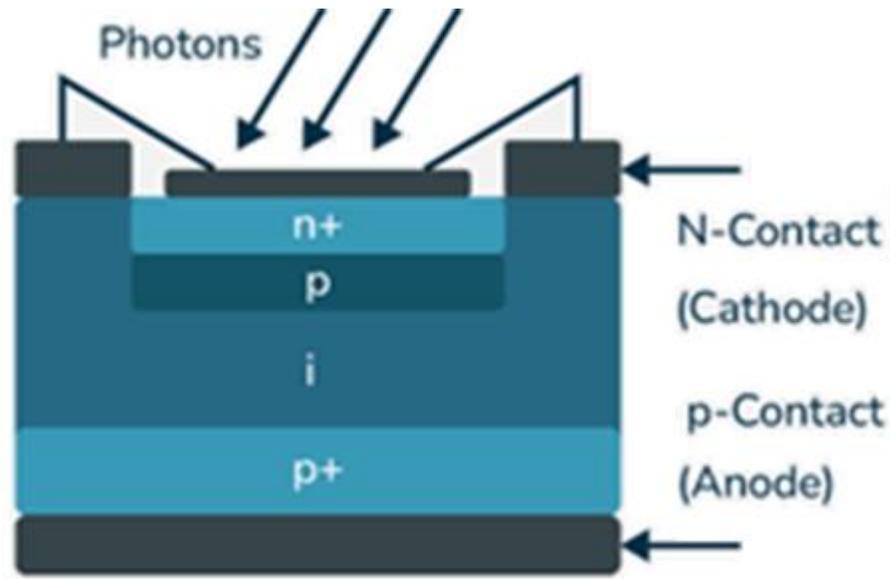
Avalanche Photodiode Structure



Specialized Photodiode Types

➤ Avalanche Photodiode (APD):

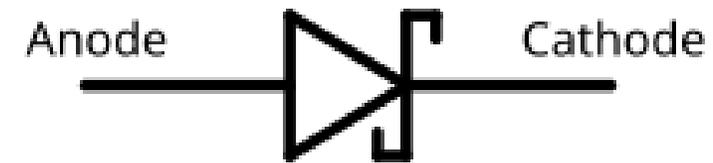
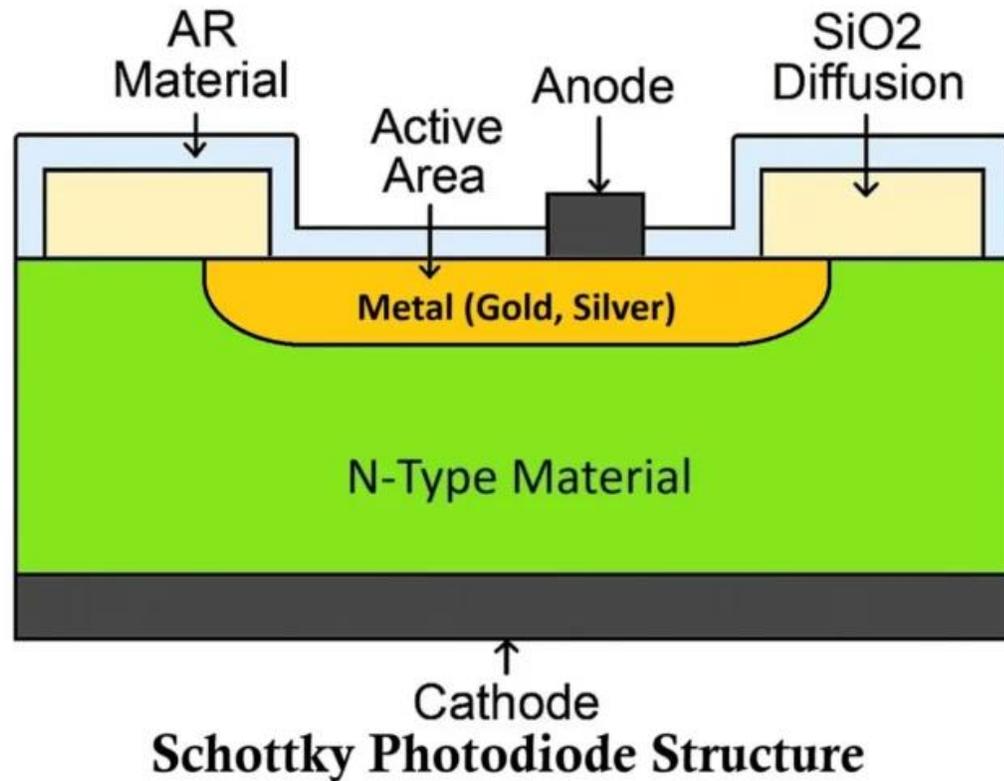
- Operates at high reverse bias to trigger **impact ionization**.



- **Benefit:** Provides internal "avalanche" gain, making it highly sensitive for long-distance fiber optics.

Specialized Photodiode Types

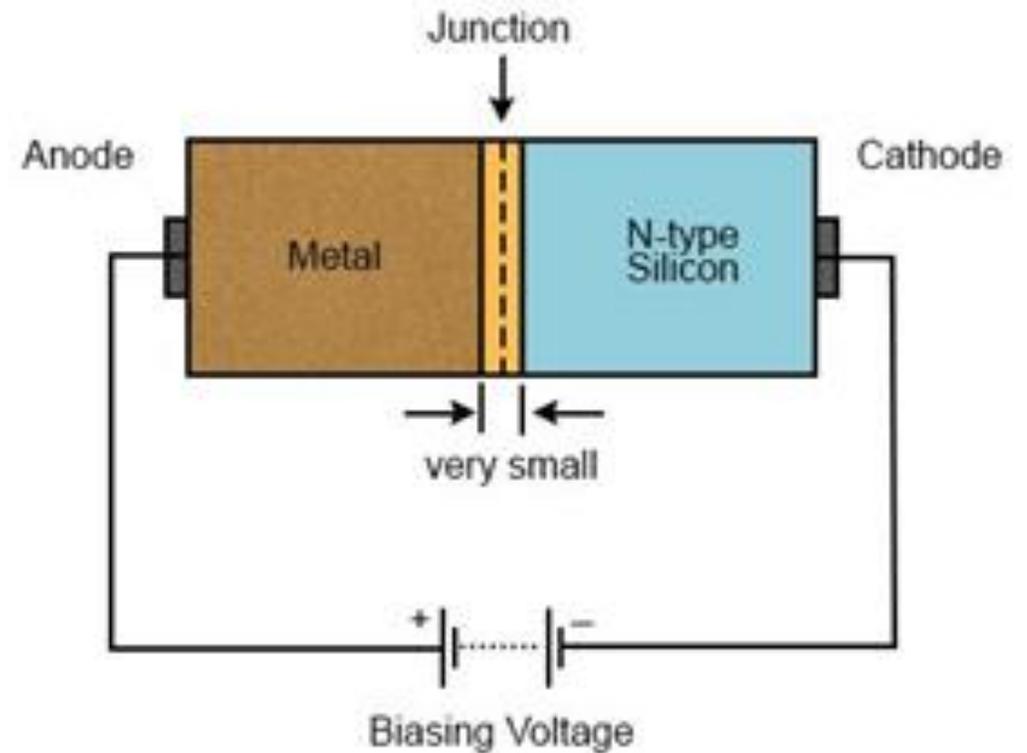
➤ Schottky Photodiode:



Specialized Photodiode Types

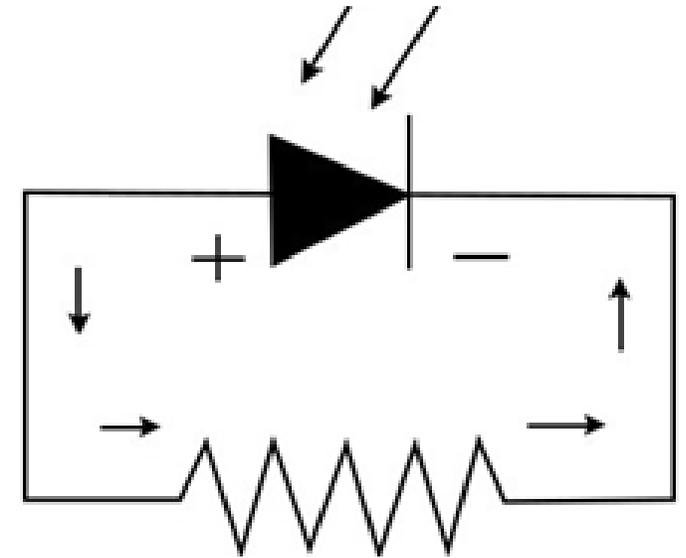
➤ Schottky Photodiode:

- Uses a metal-semiconductor junction.
- **Benefit:** Extremely fast response, often used for ultraviolet (UV) detection.

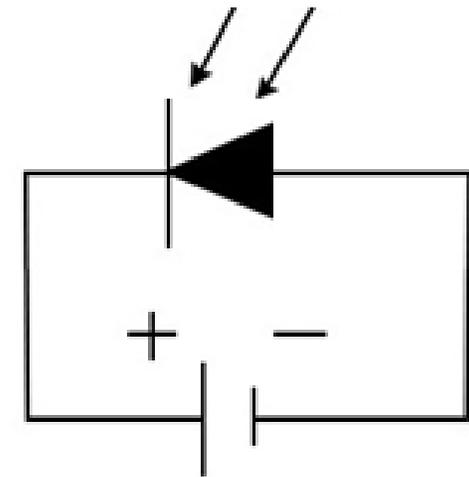


Modes of Photodiode

➤ Operation of a photodiode in Photovoltaic mode



➤ Operation of a photodiode in Photoconductive mode



Features of a photodiode

- **Spectral responsivity:** expressed in A/W.
- **Dark current:**
- **Response time:**
- **Noise-equivalent power:**

$$\text{NEP} = \left(\frac{2qI_d + 4kTB\Delta f}{R} \right)$$

noise equivalent bandwidth

$$R(\lambda) = \frac{I(\lambda)}{P(\lambda)}$$

photocurrent

incident optical power at wavelength λ

$$I_d = I_s \left(e^{\frac{qV_d}{KT}} - 1 \right)$$

charge of an electron

voltage across the diode

reverse saturation current

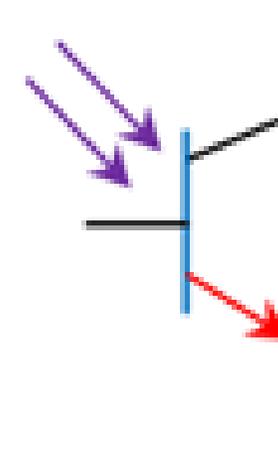
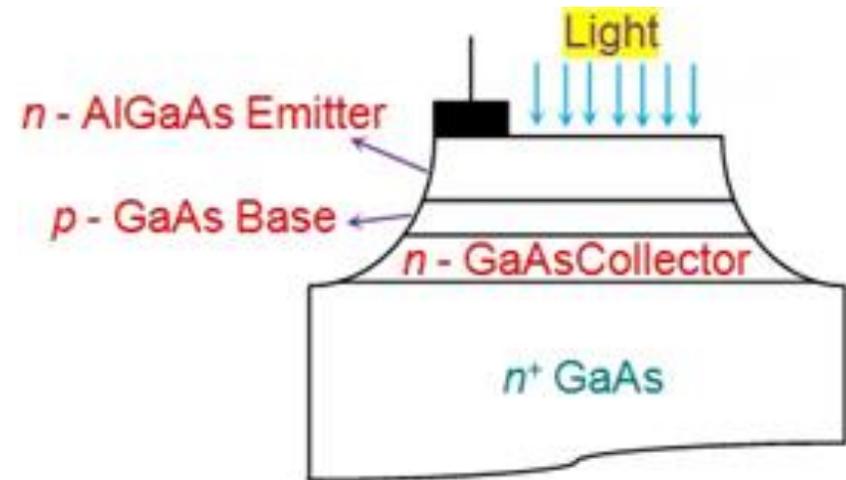
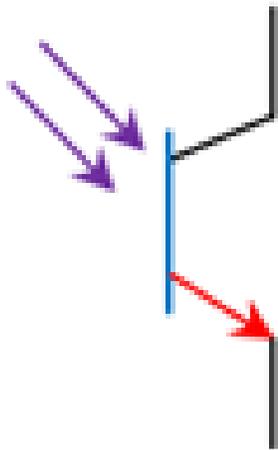
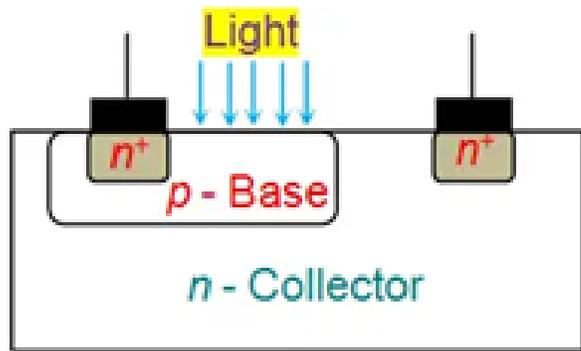
Boltzmann constant

temperature in Kelvin

$$\zeta = RC$$

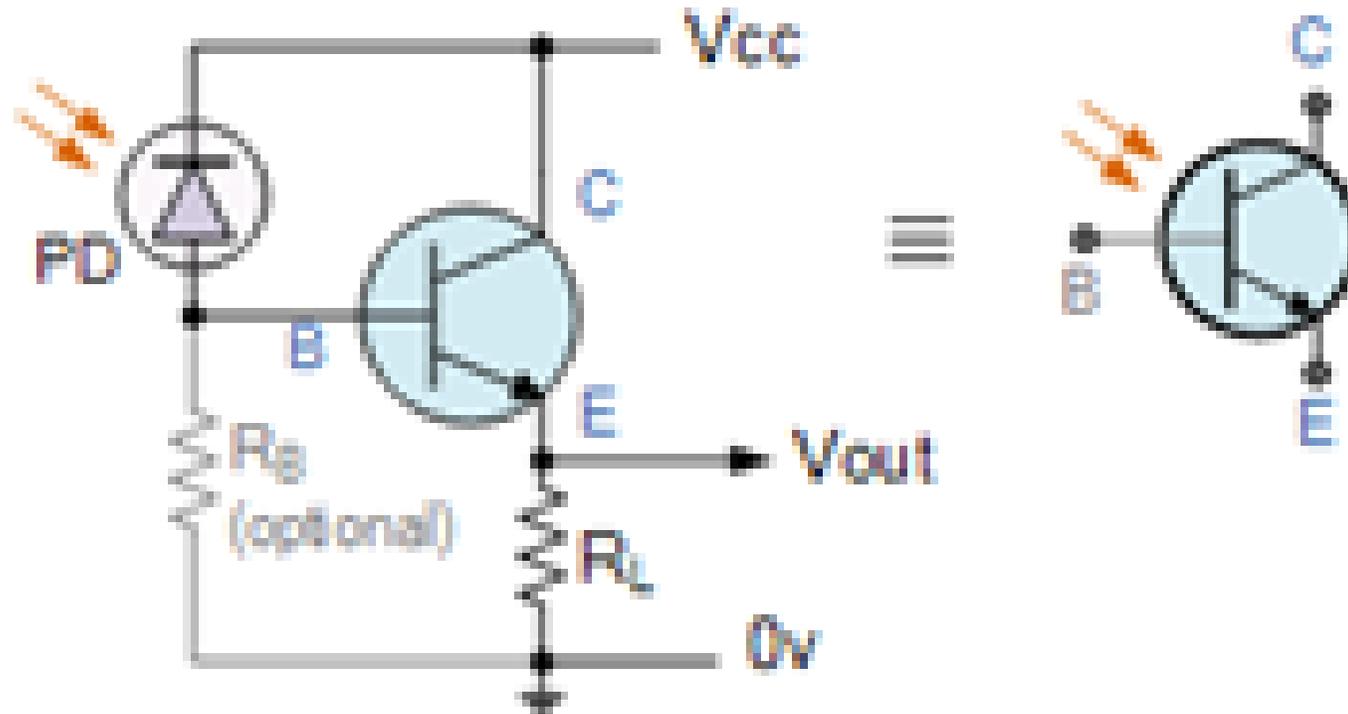
Phototransistors

- **Mechanism:** A bipolar junction transistor (BJT) where the base-collector junction is exposed to light



Phototransistors

- **Function:** It acts as both a photodiode and an amplifier. The base current is generated by incident light, which is then amplified by the transistor's gain (β).



Phototransistors

➤ **Comparison:**

- **Vs. Photodiodes:** Phototransistors have much higher sensitivity (higher output current) but are significantly slower.
- **Three-Terminal vs. Two-Terminal:** Some have a base lead for electrical biasing, while others rely solely on light to trigger conduction.

➤ **Common Use Case:** Light-activated switches and optoisolators.

End chapter 3

[Video](#)

<https://www.youtube.com/watch?v=DNAgJrnj4EM&t=43s>