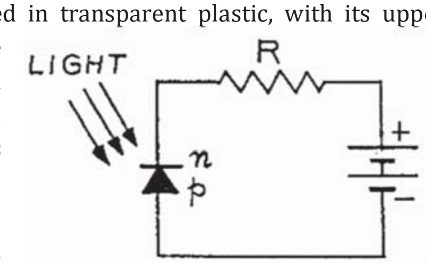
SPECIAL PN DIODES

PN diodes with special characteristics are often referred to as special PN diodes. These diodes exhibit unique properties tailored for specific applications beyond standard rectification.

Examples of special PN diodes include Zener diodes, Schottky diodes, tunnel diodes, and light-emitting diodes (LEDs), among others. Each type serves a distinct purpose, such as voltage regulation (Zener diodes), fast switching (Schottky diodes), negative differential resistance (tunnel diodes), or light emission (LEDs). These special PN diodes find extensive use in electronics, telecommunications, power supplies, and lighting applications, contributing to the versatility and efficiency of modern electronic systems.

Photodiode:

A photodiode is a semiconductor component engineered as a reverse-biased p-n junction with light-sensitive attributes. This junction is encapsulated in transparent plastic, with its upper surface deliberately exposed to light. Conversely, the other surfaces of the plastic casing are either coated in black or enclosed within a metallic enclosure. It's worth noting that the photodiode unit as a whole is exceptionally compact, typically measuring around 0.1 inches in size.



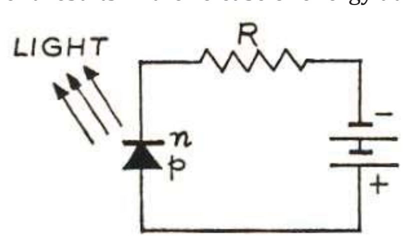
In the absence of incident light, and when subjected to a reverse bias of several tenths of a volt, the junction produces a nearly constant small current in the microampere range, referred to as "dark" current. This dark current originates from the reverse saturation current resulting from thermally-generated minority carriers, where electrons reside in the p-region and holes in the n-region.

However, when light of the appropriate frequency illuminates the junction, additional electron-hole pairs are generated near the junction due to the breaking of covalent bonds. These light-induced minority carriers traverse the reverse-biased junction, augmenting the reverse current caused by thermally-generated carriers. Consequently, the overall current in the circuit increases, typically by a fraction of a milliampere. This phenomenon, known as "photoconductive" current, demonstrates an almost linear correlation with the incident light intensity.

P-n photodiodes exhibit the ability to operate at frequencies around 1 MHz, rendering them suitable for various applications such as high-speed reading of computer punched cards, light detection systems, light-operated switches, and electronic counters.

Light-Emitting Diode (LED):

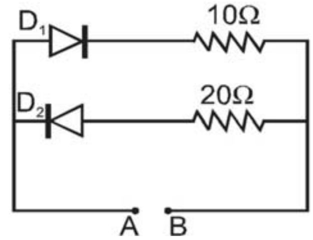
When a p-n junction diode is subjected to forward biasing, both electrons and holes migrate towards the junction. As they cross the junction, electrons combine with the holes, initiating a process known as recombination. This recombination event results in the release of energy at the junction, primarily due to electrons transitioning from a higher energy state to a lower one. In germanium (Ge) and silicon (Si) diodes, this energy release occurs as infrared radiation. Conversely, if the diode is fabricated from gallium arsenide or indium phosphide, the emitted energy manifests as visible light. These diodes are commonly referred to as 'light-emitting diodes' (LEDs).



The rise of LEDs has resulted in their extensive use, displacing incandescent lamps across various applications. This transition is attributed to their benefits, such as low energy consumption, extended operational longevity, and quick on-off switching abilities. LEDs are widely integrated into contemporary electronic devices, especially in compact gadgets like calculators, highlighting their adaptability and effectiveness.

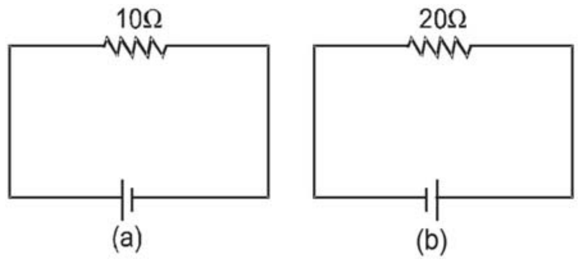
Example.

A 2V battery is connectable between points A and B, as illustrated in the diagram. Given that each diode exhibits zero resistance in forward bias and infinite resistance in reverse bias, ascertain the current supplied by the battery when the positive terminal is connected to (a) point A and (b) point B.



Solution.

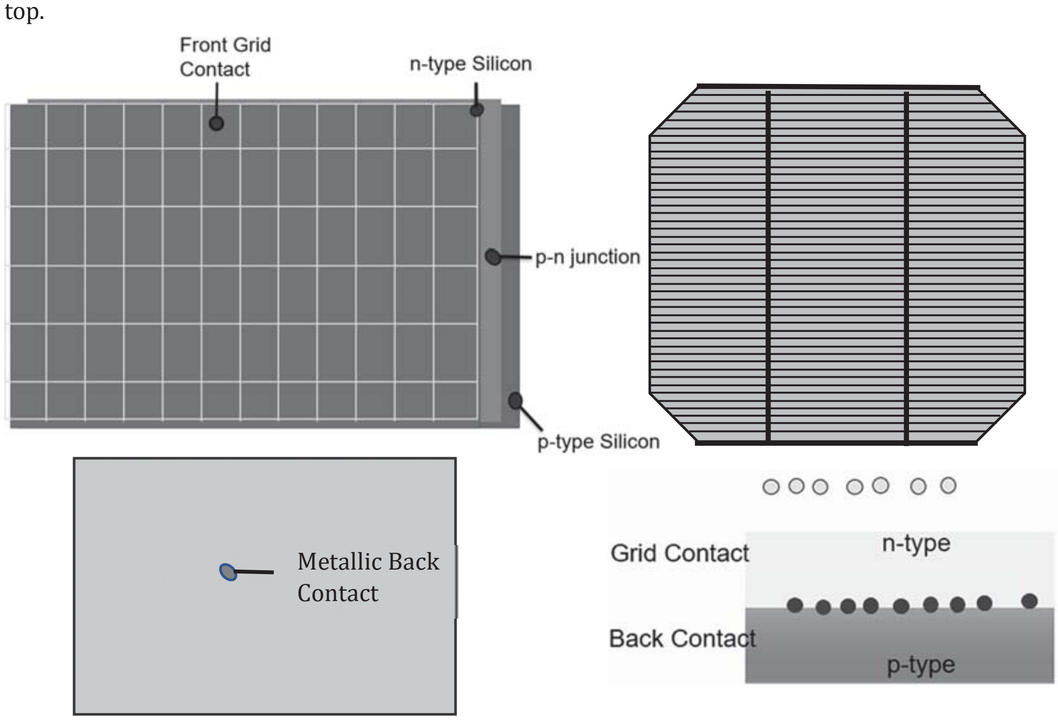
(a) When the positive terminal of the battery connects to point A, diode D1 is forward-biased, and D2 is reverse-biased. D1's resistance is negligible, akin to a wire with zero resistance, while D2's resistance is infinite, resembling a broken circuit. The resulting circuit is depicted in the figure. The battery's current can be computed as 2 V divided by 10 Ω, resulting in 0.2 A.



(b) On the contrary, when the positive terminal of the battery is linked to point B, D2 is forward-biased, while D1 is reverse-biased. The equivalent circuit corresponding to this scenario is depicted in figure (b). The battery's current flow is calculated as 2 V divided by 20 Ω, yielding a current of 0.1A.

Solar cell

A silicon wafer, initially p-type and approximately 300 μm thick, undergoes a process where a thin layer (approximately 0.3 μm thick) of n-type silicon is grown on one side through diffusion. The other side of the p-type silicon is coated with a metal, serving as the back contact. On top of the n-type silicon layer, a metallic grid is deposited, serving as the front contact. This metallic grid occupies only a very small portion of the cell area, allowing light to be incident on the cell from the top.



The n-type Si layer is deliberately thinned to allow sunlight to penetrate into the depletion region. As sunlight reaches this region, electron-hole pairs are generated. Due to the presence of an electric field within the depletion region, electrons are pushed towards the n-side while holes move towards the p-side.

Electrons reaching the n-side are gathered by the front grid contact, while holes reaching the p-side are collected by the metallic back contact. Consequently, the p-side acquires a positive charge while the n-side becomes negatively charged, resulting in the development of a potential difference. Upon connecting an external load to the cell, currents start flowing through the load.

When the solar cell is disconnected from the external circuit, the buildup of charges at both ends—holes on the p-side and electrons on the n-side—gradually reaches a peak, known as saturation. At this point of saturation, the voltage achieves its maximum value, referred to as the open circuit voltage (VOC).

When the solar cell is short-circuited, meaning its ends are connected solely by a wire:

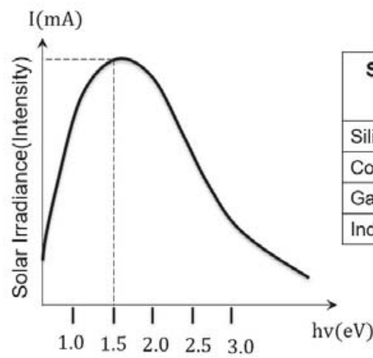
Current initiates flowing either from the n-side to the p-side within the p-n junction, or from the p-side to the n-side in the external circuit.

This current attains its maximum value because there is no resistance in the external circuit, hence termed the short-circuit current (ISC).

Given that the current flows from the n-side to the p-side within the p-n junction, it is conventionally considered negative.

The selection of material for manufacturing solar cells typically prioritizes the following criteria:

- Band-gap falling within the range of 1.0 eV to 1.8 eV.
- Strong absorption capability of solar radiation.
- Favorable electrical conductivity.
- Accessibility and affordability.



Semiconductor Material	Formula	Band-gap(eV)
Silicon	Si	1.11
Copper (||) oxide	CuO	1.2
Gallium (|||) arsenide	GaAs	1.43
Indium (|||) phosphide	InP	1.35

According to the graph, photons with energy close to 1.5 eV exhibit the highest intensity. Hence, materials selected for solar cell production typically possess a band gap ranging between 1.0 eV and 1.8 eV, as photons within this range demonstrate exceptionally high intensity.